DOCUMENT RESUME

ED 237 637 CE 036 546

AUTHOR Byrnes, Kerry J.
TITLE Diffusion and Adoption of Innovations in Fertilizer-Related Agricultural Production Technology in Developing Countries.
INSTITUTION International Fertilizer Development Center, Muscle Shoals, AL.
PUB DATE 1 Jan 81
NOTE 332p.
PUB TYPE Information Analyses (070) -- Viewpoints (120)

EDRS PRICE MF01/PC14 Plus Postage.
DESCRIPTORS *Adoption (Ideas); Agricultural Education; *Agricultural Production; Agricultural Skills; Agricultural Supplies; Agricultural Trends; Agriculture; Agronomy; Delivery Systems; *Developing Nations; Diffusion (Communication); Farm Management; *Fertilizers; Field Crops; *Information Dissemination; *Innovation; Literature Reviews; *Merchandise Information; Plant Growth; Productivity; Research Methodology; Research Reports

ABSTRACT

This monograph reviews a wide range of research literature on the diffusion and adoption of innovations in agricultural production technology in the developing countries, with particular emphasis on the practice of using commercially purchased, inorganic fertilizer as a source of plant nutrients. It is intended that the report's documentation of agronomic, economic, and social factors constraining expanded use of fertilizer in developing countries will provide guidelines for individuals and organizations charged with the responsibility for devising and implementing policies, programs, and projects to promote and facilitate expanded fertilizer use. The review is organized into eight chapters. Chapter 1 provides an introduction to the study. Chapters 2-5 review and assess not only the empirical findings from previous studies on the diffusion of innovations in agricultural production technology in the developing countries, but also the research approaches used in these studies. Chapter 6 summarizes the empirical findings that emerge from the literature reviewed in the preceding chapters, while Chapter 7 outlines some of the key ways in which these findings are relevant to the design of policies and programs aimed at accelerating the rate of diffusion of fertilizer use in developing countries. Finally, Chapter 8 provides a general assessment of the research approaches reviewed. It also lists some of the principal areas in which research is needed to improve understanding of the ways in which constraints impede and delay the diffusion and adoption of fertilizer use in developing countries. An extensive bibliography is included in the document. (KC)

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DIFFUSION AND ADOPTION OF INNOVATIONS IN FERTILIZER-RELATED AGRICULTURAL PRODUCTION TECHNOLOGY IN DEVELOPING COUNTRIES[1]

by

Kerry J. Byrnes[2]

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PREFACE

This monograph evolved from a literature review undertaken as the initial step of an International Fertilizer Development Center (IFDC) research project to identify and measure the relative impact of various agronomic, economic, and social factors on the adoption and diffusion of fertilizer use and agricultural production technology in developing countries.

Social scientists embarking on research in this area are immediately faced with the challenges of sorting out which variables are of greatest relevance and identifying what is already known about the relationships among these variables and the decisions which farmers make about the use of new technological inputs and practices. This "sorting out" process is even more difficult if the scientist attempts to utilize research contributions from studies emphasizing explanatory variables and analytical procedures from disciplines other than his own.

There is a vast and continually growing body of research literature on the adoption and diffusion of innovations in agricultural production technology. While the present monograph could not begin to catalog and synthesize all of this literature, it is my hope that the monograph will provide many useful leads for anyone embarking on or now engaged in adoption/diffusion research in the developing countries and who, accordingly, is or will become involved in this "sorting out" process.

From a practical standpoint, it is also hoped that the monograph's documentation of agronomic, economic, and social factors constraining expanded use of fertilizer in developing countries will provide useful guidelines for individuals and organizations charged with the responsibility for devising and implementing policies, programs, and projects to promote and facilitate expanded fertilizer use.

The manuscript could not have been completed without the constructive feedback and editorial assistance of several colleagues. Particularly valuable were the critiques of Dr. Thomas H. Foster, Dr. G. Edward Schuh, and Dr. George M. Beal.

Additional comments and suggestions were made by Dr. William Flinn, Dr. Gelia Castillo, Dr. Delbert Myren, Dr. Niels Roling, and Dr. Everett M. Rogers. Early drafts of the manuscript were critiqued by Dr. Christina Gladwin, Dr. Per Pinstrup-Andersen, Dr. Carlos Baanante, Dr. Mohinder Mudahar, and Dr. Surjit Sidhu. Welcome editorial input was provided by Mrs. Marie Thompson, Mr. E. D. Frederick, Dr. Francis C. Byrnes, Mr. Christopher Dowswell, and an anonymous reviewer at Iowa State University. Typing of the manuscript was done with great care and patience by Mrs. Jane Goss.

Deficiencies yet remaining in the manuscript are certainly not there because of failure on the part of my colleagues to bring such shortcomings to my attention. A sincere effort, however, has been made to respond to reviewers' critiques and, accordingly, I accept full responsibility for the manuscript's final content, organization, and conclusions.

It now remains for the reader to make his or her own judgment regarding the "state of the art" of adoption/diffusion research in the developing countries and to take up the many challenges which this field yet holds for the interested student, scientist, and practitioner.

Kerry J. Byrnes
Muscle Shoals, Alabama
January 1, 1981

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CHAPTER I

INTRODUCTION

This monograph reviews a wide range of research literature on the diffusion and adoption of innovations in agricultural production technology in the developing countries, with particular emphasis on the practice of using commercially purchased, inorganic fertilizer as a source of plant nutrients.[1] As a basic point of reference, the concepts of innovation, adoption, and diffusion are now briefly defined.

An innovation is any idea, object, or practice perceived as new by an individual. In the developing countries, there is a considerable range of experience with respect to the practice of using commercially purchased, inorganic fertilizer. While this practice is certainly not an innovation in the eyes of many farmers, for many others it is a relatively new or even yet untried procedure. In the eyes of such farmers, the practice of using commercially purchased, inorganic fertilizer (or a new technological package which requires the use of modern inputs such as improved varieties and inorganic fertilizer) is an innovation.

The concept of adoption has been defined as "a decision to make full use of a new idea as the best course of action available" (Rogers and Shoemaker, 1971:26). Historically, this definition has frequently reflected a tendency for researchers to study only, or primarily, recommended practices--those known or believed to be applicable for a wide range of conditions. Evenson (1975:744) notes in this regard "that...researchers with vested interest in the diffusion of technology usually greatly overestimate the extent of superiority of new technology." In turn, extension workers "also lend substance to the myth of the broadly superior technology package because of the necessity of recommending a simple package to large numbers of farmers" (Evenson, n.d.). It is therefore not surprising, as Rogers (1975:12-13) has argued, that adoption research has similarly had a "pro-innovation bias," i.e., an assumption that the innovation studied is "good" and should be adopted by everyone.

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[1] The principal nutrients supplied by such fertilizers are typically nitrogen (N), phosphorus (P), and potassium (K) (FAO, 1965). See also IFDC (1979), Kemmler (1980), FAO (1980), and von Peter (1980).

While the study of the factors influencing a technology's adoption by the farmer may be facilitated by the assumption that the technology is superior to any other technology for all farmers in an area, this is typically not the case, since most agricultural technology is highly sensitive to resource scarcities and resource characteristics. Since it is increasingly clear that use of a particular innovation may not be "the best course of action available" to an individual farmer, the concept of adoption would more appropriately be used to refer to the decision by an individual to continue using an innovation either wholly or in part, following a period during which he uses it for the first time. The first-time use of an innovation during such a period of experimental or small-scale use is conventionally referred to as a trial.

This definition of adoption does not imply "that once an input is adopted it stays adopted." The definition does say that a farmer's decision to continue using a particular innovation in whole or in part, after an initial trial period of experimental or small-scale use, is a decision to adopt the innovation. And the innovation stays adopted--continues to be used--until such time that the economics of the situation and/or other factors persuade the farmer to discontinue its use in favor of some alternative practice.

In contrast to adoption as an individual phenomenon, diffusion is a social phenomenon which may be defined as the spreading of an innovation from its original source of invention or discovery (e.g., an experiment station or a farm-level applied research or demonstration plot) to one or more individuals (e.g., farmers) who are the first or among the first to adopt the practice, then to other individuals who subsequently adopt it, etc.

As a process, the diffusion of an innovation involves:

1. the innovation;
2. information about the innovation;
3. communication of such information, over time and space, to potential adopters;
4. a channel or medium through which such information is communicated;
5. the individual's evaluation of whether or not to adopt the innovation or at least to try it;
6. allocation of resources for acquisition of the innovation or the requisite inputs for a trial of it;
7. trial of the innovation; and, finally,

8. an adoption decision, i.e., a decision to either discontinue use of the innovation or to continue its use either at the same level of application as in the trial or at some modified level of application. As is the case with fertilizer use, a decision to adopt or continue using a particular innovation also implies a decision about the intensity of use of that innovation (e.g., how much nitrogen to use per hectare).[2]

THE PROBLEMATIC SETTING

Large segments of the world's population, increasing at over 80 million persons a year, currently suffer or are threatened by malnutrition, hunger, or starvation (IFDC, 1975; Mauldin, 1980).[3] While actual or potential food deficits are greatest in the developing countries of Africa, Asia, and Latin America, these areas also have the greatest potential for substantially increasing food production. Many factors, however, operate to restrict a rapid expansion of food and agricultural production.

Although the factors entering into a solution to the food problem are numerous and complex in their interrelationships, one of the key requirements is to significantly expand the use of productivity-increasing agricultural technology. Such technology consists of many different inputs, including the so-called high-yielding varieties (HYVs) of seed (e.g., "miracle" rice varieties such as IR-8) and complementary inputs such as irrigation, fertilizers, pesticides, weed control measures, and proper timing in the application of these inputs as well as other management practices (cmpr. Barker, 1971). When these inputs are effectively combined, the farmer can dramatically increase his yields or productivity per unit of land on which the new technology is applied. While each of these inputs is important in its own right, the significance of fertilizer lies in the dramatic increases in yield which can be achieved if this input is properly used.

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[2] This view emphasizes what may be termed the demand side of the diffusion process. A supplementary or broader perspective, emphasizing the supply side of the diffusion process, is reviewed in Chapter II's discussion of the market and infrastructure context of innovation adoption and diffusion (cmpr. Brown, 1977).

[3] There is a growing body of references relative to world food problems. Among these are: Berg (1973), World Bank (1974:181), McIntosh (1975), Economic Research Service (1975), Spivey (1975), Wortman (1975, 1980), IFPRI (1976), World Food Conference (1977), World Food and Nutrition Study (1977), Wortman and Cummings (1978), Lappe and Collins (1978), D'Silva and Tracy (1978), Center for the Analysis of World Food Issues (1979), Scrimshaw (1980), Presidential Commission on World Hunger (1980), and World Bank (1980). Also pertinent is the body of literature focusing on the so-called Green Revolution (Palmer, 1976; Pearse, 1977; Farmer, 1977; Dahlberg, 1979; Pinstrup-Andersen, 1979a; and Gibbons et al., 1980).

Available statistical data indicate that the intensity of use of fertilizer is low in the developing countries. For example, in Asia, fertilizer consumption (i.e., total quantity of fertilizer used) is only 20% that of the industrialized countries (Ping, 1979:33). The status of use of fertilizer in the developing countries may be seen in statistics reviewed by Pinstrup-Andersen (1976a, 1976b). Estimates for 1974 reveal an average of 18.6 kg of nutrients (N, P_2O_5, K_2O) per hectare of arable land in developing market economies as compared with an average of 109 kg/ha in developed market economies.[4] Although only a small proportion of total food production in most countries can be attributed to fertilizer, a sizable part of increased production has been brought about by increasing fertilizer use along with the planting of new fertilizer-responsive crop varieties and the application of other improved technology. Recent estimates indicate that approximately 15% of the total cereal production in developing market economies for the year 1972-73 was realized through the application of fertilizer. Similarly, the application of fertilizer provided an estimated 30% of the increase in cereal production in these countries between 1948-52 and 1972-73. Looking to the future, it is estimated that expanded fertilizer use will account for 36% of the projected increase in cereal demands in developing market economies until 1980-81. Fertilizer will also be important in the expansion of the production of crops other than grains.

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4. In using fertilizer, a primary consideration is the "grade," defined as the nutrient percentage of the product by weight and expressed as a set of three numbers in the order of percentage of total nitrogen (N), available phosphate (as P_2O_5), and soluble potash (as K_2O). In recent years, most of the scientific community has adopted "elemental" expressions, P and K, for phosphorus and potassium in lieu of the "oxide" expressions, P_2O_5 and K_2O. For conversion from one factor to another, use the following factors.

To convert oxides to elemental, multiply the P_2O_5 value by 0.4369 and multiply the K_2O value by 0.8302.

To convert elemental to oxides, multiply the P value by 2.2886 and multiply the K value by 1.2046 (Slack, 1976:53-54). See also FAO (1965).

It is important to recognize that the magnitude of the contribution of expanded use of fertilizer to food and agricultural production may be influenced by a host of other factors, only some of which can be manipulated. If such manipulation, whether through policy, programs, or projects, is to be successful, it will have to be based on identification of the constraints to expanded use of fertilizer prevailing in the environment in which the farmer operates and knowledge of how these constraints interact and affect the initial and continuing use of fertilizer.

In light of the recognized need to develop a better understanding of the factors constraining expansion of fertilizer use in the developing countries, this monograph's focus on the adoption and diffusion of fertilizer use in such countries becomes important and urgent. Will the farmer decide to use fertilizer and complementary inputs? What are the factors or variables that will determine the farmer's decisions? Are these factors subject to manipulation in a way that will expand the economically sound or efficient use of fertilizer? And, if so, which variables should be manipulated?

While answers to these questions would significantly contribute to an understanding of the process of agricultural development in the developing countries, a casual review of the literature of previous diffusion research may leave one with the impression that a significant contribution has not yet been realized.

For example, as Falusi (1974:3) has observed, numerous diffusion studies have been conducted:

> ...to find out the factors that influence the adoption of...innovations mainly by agricultural extension specialists, rural sociologists, and agricultural economists.... More often than not the results of these studies have tended to be rather qualitative in nature. While suggestive of policy implications, they do not provide a basis for an assessment of the quantitative impact of various policy instruments.

Dissatisfaction with research on the diffusion of agricultural technology is also voiced by Mosher (Introduction to Byrnes, 1968):

> In few areas of research related to agricultural development have the traditional divisions among academic disciplines been more disastrous than in studies of the adoption of improved practices by farmers. Whether the persons making such a study be an agronomist, an economist, a sociologist, a communications expert or an anthropologist, the tendency has been for each to "explain" farmers' behavior predominantly in the light of the variables traditionally dealt with by the academic discipline represented by the investigator.

Roling (1970:71:72) carries the critique of diffusion studies one step further with the observation that:

> ...much energy [has been devoted] to the study of the diffusion of innovations among farmers. This devotion has led to the development of an impressive body of findings, especially in the United States. One cannot, however, escape the feeling that a stalemate has been reached. Adoption studies are completed one after the other, the list of variables related to innovativeness is regularly expanded, but the findings have not been integrated into a more general theory of human behavior. This has halted the qualitative progress of research. Many phenomena are left unexplained, cannot be interpreted, or seem incorrectly interpreted.

Holden (1972:463) points out that:

> ...the relatively small amount of work in [the field of diffusion research] outside of North America has not gone very far in testing basic assumptions. Instead, it appears to have been a series of exercises to see whether the earlier findings would hold elsewhere.

As a result, Holden (1972:467) concludes, there has been "a failure to collect data which might be more revealing in non-North American and non-European societies."

Several critics provide a number of leads regarding what "more revealing" data, i.e., variables, might include. Byrnes (1966:242), for example, writes:

> If we review their reports we might well conclude that the social scientists who study the processes related to farmer acceptance or rejection of new practices must assume that the major dynamics associated with diffusion in agriculture are limited to the farmer and his social and physical environment. There is a scarcity of reported studies in which scientists have tried to measure the rate or extent of practice adoption in relation to the technical adequacy of the change agent or the technical appropriateness of the practice advocated.
>
> Perhaps social scientists have avoided such study because of the attendant difficulties of measurement, or they may have assumed that satisfactory levels of adequacy and appropriateness existed. This latter situation may occur in developed countries with well-established extension services, but it is extremely unlikely in most underdeveloped areas where the research and extension agencies also are developing.

The technical adequacy of the extension worker is particularly important. If the farmer believes that the extension worker's advice is too general and is not suitable for his specific environment, then the likelihood that he will adopt the recommended practice is considerably reduced.

The technical adequacy of the extension worker and the technical appropriateness of the innovation advocated, however, are not the only "missing variables" in research on the diffusion and adoption of innovations in agricultural production technology in the developing countries. For example, Aiken, et al. (n.d.), cite the "neglected role" of structural factors, such as institutional constraints:

> Studies on...adoption...appear to accept a set of implicit assumptions...about change.... In effect, previous studies have assumed equal access [to the] resources necessary for the adoption of the innovation and equal positive evaluation of the consequences of the innovation. ...panel data demonstrated that...Colombian farmers do not have equal access to institutional resources or support for adopting new technology in agriculture. Thus, when structural aspects of the adoption situation are taken into account, ...institutional constraints have equal, if not more powerful explanatory effects than personal characteristics of the innovators.

Galjart (1971:31) also notes that "structural variables were not often taken into account by rural sociologists; most of their research aimed at explaining the variance in innovativeness among individual farmers living in a single community." Similarly, Havens (1967:104) has argued that "past adoption studies concerning the use of new agricultural techniques have largely overlooked the structural arrangements within which adoption occurs." Based on a study of adoption of innovations in India, Hodgdon (1971) concluded that there is a

> ...need, indeed a necessity, of designing adoption research in India and in other developing countries to focus not alone on the individual farmer as decision-maker and actor, but upon the numerous social systems and the different levels of interaction which affect the decision-making process, and thus impede adoption....

Obviously, there is a need to design diffusion studies in the developing countries in light of a stronger theoretical base. As Rogers (1962:296) notes:

> Future efforts need to select independent variables...with more attention to theoretical considerations. . . . The raw empiricism of this past research era has served a useful purpose, but it is now time to set forth a model to explain theoretically how adoption of an innovation takes place in a social system.

Exactly which variables and relationships among variables would be specified in an adequate theory or model of diffusion, however, is yet a point of much discussion and debate in the literature (cmpr. Singh, 1972; Warner, 1974).

For example, commenting on those American rural sociologists who have studied adoption, Albrecht (1965:2) writes:

> The leading American rural sociologists who work in adoption research...consider...the theoretical approach insufficient on which...studies have been based. The feeling that really relevant factors have not been recognized and dealt with methodologically...results... in resorting to basic and allied disciplines in order to make use of achievements made there.

Rural sociologists, however, have not been alone "in resorting to basic and allied disciplines in order to make use of achievements made there." In view of the traditional tendency for each discipline to focus on one or more significant variables which remained largely ignored by other disciplines, this more recent trend toward interdisciplinary cross-pollination is most promising.

While the field of diffusion research has been heavily criticized, as evidenced above, the present literature review attempts to provide a basis for some conclusions regarding factors which affect the rate of diffusion of fertilizer use. It also suggests ways for accelerating the diffusion of fertilizer use.

NATURE OF THE REVIEW

This monograph endeavors to:

1. Review and evaluate the generalizations that can be drawn from the empirical findings of past research in the developing countries on the diffusion of innovations in agricultural production technology, with particular emphasis on fertilizer use and complementary inputs.

2. Outline some of the key ways in which the review's empirical findings can be used to develop policies and programs aimed at accelerating the rate of diffusion of fertilizer use in developing countries.

3. Review and assess the utility of available research approaches for identifying and estimating the relative importance of the factors affecting the rate of diffusion of fertilizer use.

4. Indicate those areas in which research is needed to improve the understanding of the ways in which economic and social factors influence the rate at which the practice of fertilizer use diffuses in the developing countries and how this process can be accelerated.

ORGANIZATION OF THE REVIEW

Chapters II through V review and assess not only the empirical findings from previous studies on the diffusion of innovations in agricultural production technology in the developing countries, but also the research approaches used in these studies. To facilitate the discussion, the review will examine, in turn, geographical, economic, and sociological approaches to diffusion research. Empirical findings from research approaches less clearly tied to any one discipline are also reviewed in a separate section. Each research approach is described and evaluated in terms of the extent to which that approach permits generalization about the relative importance of the variables or factors which constrain the adoption and diffusion of fertilizer use in the developing countries. Various secondary data in the form of qualitative descriptions (e.g., statements made by farmers during interviews), frequency tabulations or percentage distributions from survey data, and inferential statistics (e.g., correlation coefficients) are presented throughout these chapters. These data illustrate the empirical application of specific research approaches and provide a basis for identifying what may be said in a general way about the variables that influence the adoption of fertilizer use in the developing countries. A large number of references (cmpr. Jones, 1967; Rogers, 1962; Rogers and Shoemaker, 1971; Rogers and Thomas, 1975; Myren, 1965; Brown, 1968; Harton, *et al*., n.d.; Singh, 1972; Warner, 1974; Schutjer and Van Der Veen, 1976; and Radnor, *et al*., 1978) were searched to identify potentially relevant literature. In view of the review's broad coverage of literature relating to different disciplines, research approaches, and countries in which empirical research has been conducted, the author recognizes that potentially relevant studies may have been overlooked.

Chapter VI summarizes the empirical findings which emerge from the literature reviewed in the preceding chapters.

Chapter VII outlines some of the key ways in which these findings are relevant to the design of policies and programs aimed at accelerating the rate of diffusion of fertilizer use in a developing country.

Finally, Chapter VIII provides a general assessment of the research approaches reviewed. It also lists some of the principal areas where research is needed to improve understanding of the ways in which constraints impede and delay the diffusion and adoption of fertilizer use in developing countries.

GENERAL HYPOTHESIS

It may be helpful here at the outset to advance the general hypothesis that the likelihood that a farmer will adopt a particular innovation such as fertilizer use is inversely related to the number and/or magnitude of the variables or factors that constrain economic use of that innovation. Generally, three sets of processes may operate, individually or in combination, to facilitate or impede adoption of an innovation by farmers: communication, evaluation, and implementation. This hypothesis derives, in part, from the writings of three social scientists who have conducted research on the adoption of innovations (Feaster, 1968; Havens, 1967; and Galjart, 1971). As demonstrated in the following, each of these researchers has proposed basically the same three variables or factors to explain why farmers do or do not adopt innovations in agricultural production technology.

Model 1

Numerous factors have been suggested in many adoption studies as explaining why farmers do not adopt innovations that would, if used by the farmer, increase productivity and income. For example, lack of motivation or lack of innovativeness on the part of the farmer, often attributed to traditional values and beliefs prevalent in the farmer's social and cultural environment, are frequently mentioned. Such factors may in some instances account for failure to adopt a recommended innovation. However, as Feaster (1968) suggests, there are three other factors which may explain the failure equally well, if not better:

1. technologies that are agronomically better than those in use do not exist or remain unknown to farmers;

2. agronomically superior technologies exist, but they are not economically feasible under existing factor/product price ratios and the farmer's subjective rate of discount; or

3. agronomically and economically superior practices exist but their availability to or adoption by the farmer is restricted by one or more constraints in the farmer's environment.

Model 2

A similar model is proposed by Havens (1967) in which adoption is the result of decision-making or choice-making on the part of the farmer. This, of course, presupposes that the farmer is "free" to choose between alternatives (e.g., different technologies which might be adopted). Several conditions, however, are essential in order for the farmer to indeed have a "free" choice. These are:

1. There must be available a cost-reducing, benefit-increasing, and/or risk-reducing alternative technology to the technology currently used by the farmer.
2. The farmer must be aware of and possess knowledge about the alternative technology.
3. The farmer must possess sufficient capital resources or have access to the credit needed in order to acquire the materials (inputs) required for a trial of the alternative technology.

If any of these conditions is missing, the farmer really does not have a "free" choice. As long as decisions, supportive of the action (e.g., adoption) which the farmer wishes to take, are not made by others (e.g., those who define what a region's credit policies or supply will be), the farmer's own decision-making will remain severely impeded or constrained.[5]

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[5] Havens (1967:97) proposes two additional conditions: (1) The alternative technology should be compatible with the values and norms of the social system in which the farmer lives. "If the innovation is compatible with the existing norms and values, acceptance, all other factors being equal..., should be accelerated" (Havens, 1967:97). (2) The alternative technology should not be perceived by the existing power structure as a threat to the structure. "If acceptance of the innovation is perceived by the power holders as a threat to their position, they may repress information about the innovation" (Havens, 1967:97).

Model 3

Galjart (1971:36,35) proposes a model which is based on a recognition that previous diffusion (adoption) researchers have "been preoccupied with the spread of technical information" and "have focused their research too exclusively on the factors *ignorance* and *unwillingness*, disregarding the factor *inability*..." (emphasis added). Galjart (1971:34) proposes that

> ...it seems wiser to...attempt in each actual case to determine what...factors *impede* the development of agriculture. Such factors may be classified under... three headings:
>
> 1. Ignorance: the farmer does not know what he can do other than what he is currently doing.
>
> 2. Inability: the farmer knows what he could do but is unable to do it for financial or other reasons.
>
> 3. Unwillingness: the farmer knows what he should do and can do, objectively speaking, but does not want to: certain values and attitudes prevent him. Another way of putting it is that he prefers to achieve some other value.

A cursory examination of table 1 which summarizes these three models reveals that all of these models basically contain the same three factors. When the similar or identical factors or variables are grouped together in the same column of table 1, it becomes clear that a comprehensive model of the processes which facilitate or impede adoption and diffusion of an innovation should take into account three distinct processes that bear on farmer decision making. These processes may be designated as communication, evaluation, and implementation, respectively.

The term *communication* is used to refer to the passing or flow of information about a particular innovation (e.g., a recommendation to use fertilizer, information about the right quantity of fertilizer to apply, etc.). The term *evaluation* is used to refer to the criteria which may be used by the farmer to determine whether use of a recommended innovation will significantly increase the profits from his farming operation. As will be noted in greater detail below, other aspects of the innovation may be considered important by the farmer (e.g., observability,

Table 1. Communication, Evaluation, and Implementation: Three Essential Processes in the Diffusion of Innovations in Agricultural Production Technology (Emphasis in quotes added by author)

	Communication	Evaluation	Implementation
Model 1 Feaster (1968)	"alternative technologies that are agronomically superior under local conditions either do not exist or *remain unknown to* farmers"	"agronomically superior technologies exist but are *not economically feasible* under existing factor/product price ratios and subjective rates of discount on the part of the farmer"	"agronomically and economically superior practices exist but their *availability* to or adoption by the farmer is *restricted by any of a number of possible constraints*"
Model 2 Havens (1967)	"The farmer must *be aware of* and *possess knowledge about* the alternative technology"	"There must be available a *cost-reducing*, *benefit-increasing*, and/or *risk-reducing*, alternative technology to the technology currently used by the farmer"	"The farmer *must possess sufficient capital resources or have access to the credit needed* in order to acquire the materials (inputs) required for a trial of the alternative technology"
Model 3 Galjart (1971)	"*Ignorance*: the farmer does *not know* what he can do other than what he is currently doing"	"*Unwillingness*: the farmer knows what he should do and can do, objectively speaking, but does not want to: *certain values and attitudes prevent* him. Another way of putting it is that he prefers to achieve some other value."	"*Inability*: the farmer knows what he could do but is *unable to do it for financial or other reasons*"

compatibility, reliability, trialability, etc.). Finally, the term implementation is used to refer to those conditions which enable the farmer to combine the resources (e.g., land, labor, etc.), institutions (e.g., security of tenure, credit, etc.), and/or capital inputs (e.g., improved varieties, chemical fertilizer) essential for the initial (trial) and continuing use (adoption) of the innovation.

Leagans (1979), summarizing 12 Ph.D. dissertations written during a 10-year research program in extension education at Cornell University, presents a similar hypothesis or model tentatively termed as the "interdisciplinary behavioral differential model." The model proposes that the farmer's adoption behavior is

> ...primarily dependent on the differential effect of the perceived cumulative valences of incentives and disincentives related to adoption. The cumulative differential valence perceived (CDVP) by farmers... influences their adoption behavior, which is to accept or reject new agricultural practices (Leagans, 1979:40).

Here the terms incentives and disincentives are considered as the reasons a farmer decides to adopt, or not to adopt, an agricultural innovation. An incentive is defined as any factor that motivates a farmer to adopt an agricultural innovation. Thus, a disincentive is any factor that inhibits the farmer from adopting the innovation. The valence of an incentive or disincentive refers to its strength as each farmer sees it.

While the specific factors relevant as incentives and disincentives will vary from one situation to the next, Leagans (1979:22) suggests that three primary environmental factors--communicational, economic, and social--are the most relevant.[6] The reader will note that Leagans' communicational, economic, and social factors are similar, if not identical, to this author's view that communication, evaluation, and implementation processes, respectively, affect the decisions which farmers make about whether or not to adopt a particular agricultural practice (cmpr. Rochin, 1978; Molina-Filho and Kawakami, 1980). However, as the following review of the literature demonstrates, different approaches to diffusion research have resulted in varying degrees of clarification about the relative importance of each of these three factors in the adoption and diffusion of fertilizer use in the developing countries.

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[6] The research (Ph.D. dissertations) in extension education referenced by Leagans include: Atayi (1977), Bakker (1977), Contado (1968), Dhillon (1970), Dwarakinath (1973), Lowdermilk (1972), Misiko (1976), Salvi (1971), Sharma (1974), Sheppard (1970), Terasart (1977), and Vidyarthy (1967). See also Leonard (1977) and Stavis (1979).

CHAPTER II

GEOGRAPHICAL APPROACHES TO DIFFUSION RESEARCH

Central to geographical approaches to research on diffusion is the "spatial distance" hypothesis, namely, that spatial distance is a key variable in determining the rate of diffusion of an innovation in a specified geographical area. Several types of spatial distance are influential in determining the pattern of diffusion of an innovation in a particular geographic region:

1. The distance between the point(s) at which a technology is initially introduced (e.g., the farm on which a technology is initially adopted) and the holdings of other farmers who are potential adopters.

2. The distance between the potential adopter and markets for selling the commodity grown in conjunction with utilization of the technology in question.

3. The distance between the potential adopter and sources of credit and/or input supplies which the farmer needs in order to adopt the technology in question.

4. The distance between any two potential adopters expressed in terms of the declining probability of communication about the technology as the cost of such communication increases with distance.

This last factor is referred to in the geographical literature on diffusion as the Mean Information Field (MIF), i.e., that the probability of contact between one person (self) and any other person (other) will decline with increasing spatial distance between self and other (Garst, 1972:38). As distance between a "teller" and any potential "hearer" increases, the probability of a message being passed between parties decreases. This probability will also be affected in a specific geographical region by the region's density of population, transportation and communication systems, and personal characteristics of the potential adopters.

Another concept used in geographical research on diffusion is that of the "innovation wave" which Garst (1972:60) defines as follows:

> The basic idea is that an innovation is introduced in some location by either chance or design, after which...[there is]...an outward movement in a wave-like pattern such that over a series of time periods, places further away will begin to adopt the innovation at the same time close-in places are increasing the rate of use.

While interest in the impact of spatial distance on the rate of diffusion of an innovation has not been confined to any one discipline, the principal contributions to the empirical testing of the "spatial distance" hypothesis have been made by geographers. Torsten Hagerstrand (1952, 1964) applied Monte Carlo simulation to the study of spatial diffusion and the technique has been used in empirical studies by Ramachandran (1969) in India and Garst (1972, n.d.) in Kenya. Innovation adoption and diffusion studies conducted by geographers employing other analytical techniques are also available in the literature. For example, Bigelow (1973) employed factor analysis and an "impact index" to study the impact of selected agricultural schemes on the innovation patterns of traditional farmers in Ghana (cmpr. Songsore, 1979).[7] Rorabacher (1978), employing multiple regression analysis, studied various socio-economic factors affecting the spatial diffusion of agricultural innovations in India. Reviews and syntheses of the geographical literature on diffusion research are presented in Brown (1966, 1967, 1975, n.d.).

MONTE CARLO SIMULATION

Hagerstrand used Monte Carlo simulation to produce an operational spatial diffusion model. Brown (1968:63-64) summarized the most restrictive model proposed by Hagerstrand as follows:

1. The number of adopters at the beginning (time 0) is designated as 0.

2. Adoption takes place after a single message is received.

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[7] An example of the use of factor analysis in diffusion research is presented in Chapter V.

3. Only interpersonal communication is considered.

4. Time is treated in discrete units of equal intervals.

5. Messages are sent only by adopters, and every previous adopter sends a message.

6. Receivers may be adopters or nonadopters.

7. The probability that any message will reach its intended destination varies inversely with the distance separating the teller and potential receiver.

8. If a previous adopter receives a message, the message is lost, i.e., it has no effect and is not repeated.

9. Whether an event takes place is decided on the basis of random numbers.

To make this model operational, the researcher must estimate and apply a Mean Information Field, i.e.,

> ...a series of probabilities mounted on a 5 x 5 movable grid which indicates the probability of successful communication between the central cell of the grid and all other cells, and within the central cell itself (Brown, 1963: 1-2).

In a Monte Carlo simulation, such a grid is placed:

> ...over a similarly gridded map, centered upon each possessor of the innovation [at] time t, and a random number drawn to determine which of the 25 map cells would receive a message to innovate in time t + 1. This Monte Carlo process, then, gives rise to a pattern of origin-destination flows of messages, and this pattern may be considered a communication network. . . . ...for each message sending operation, MIF probabilities are modified in accordance with the number of farmsteads in the destination cells. The sum of these adjusted probabilities is always one (Brown, 1963:2).

This version of Hagerstrand's use of Monte Carlo simulation is the most restrictive model in that it provides a very simplified approximation of the process of an innovation's spatial diffusion. Other versions reduce the restrictions, i.e., increase the model's complexity, by changing one or more of the restrictive model's rules. For example, rule 2 can be replaced with an alternate rule as follows: "Adoption takes place after a specified number of messages are received, the specified number varying according to the individual's resistance to adoption." The "resistance to adoption" variable can then be simulated in each "message sending operation" by drawing at random either a 1, 2, 3, 4, or 5, thereby specifying whether the message recipient (potential adopter) will require one, two, three, four, or five "tellings" before adoption takes place.

CRITIQUE OF MONTE CARLO SIMULATION

While Monte Carlo simulation has not been the only methodology used in studying the spatial diffusion of innovations (cmpr. Bowers, 1973), Brown and Moore (1969:140) argue that none of the other methodologies (e.g., the Markov chain) offers "an acceptable alternative to that of [Monte Carlo simulation as used by] Hagerstrand." In reviewing the various mathematical models now used by geographers, Brown and Moore (1969:142) conclude:

> ...that the researcher's conceptualization of the diffusion process is moulded to fit the form and assumptions of existing mathematical models, rather than vice versa. The need, then, is for a model which emanates from the...form of the researcher's conceptualization. This requires a thought process which begins with the characteristics of the conceptual framework, rather than with the existing models....

While Brown and Moore (1969:142) note that the "exact method by which this task may be carried out is not immediately apparent," a review of the literature suggests various problems that need to be solved in order to devise a more productive means of using Monte Carlo simulation in the study of spatial diffusion.

First, if a simulation model is run several times with the same data, each output will differ because of the different patterns of numbers randomly selected. While researchers have attempted to compensate for this by computing an average or mean from a large number of simulations for a specific model (cmpr. Stanfield, et al., 1965a), the variance of the resultant predictions is quite large, approximately ±10% of the population by the last time period.

Second, in the "approaches used by contemporary location-oriented researchers, ...each time interval is taken to represent a large amount of real-world time, such as a year" (Brown and Moore, 1969:148). Such a time interval was used in the research of Huke and Duncan (n.d.) on the diffusion of HYV rice in the Philippines between 1966 and 1969. However, since the decision making of farmers occurs within discrete time intervals, e.g., within and between two or more cropping seasons during 1 year, using a year as the time interval is not only

> ...a crude approximation to real-world conditions, [but] also has consequences for the task of model evaluation: the strict comparison of simulated diffusion patterns with real-world ones is not possible because the researcher cannot be sure which segments of model time compare to a given segment of real-world time (Brown and Moore, 1969:148-149).

Third, unlike regression analysis' provision of R^2, a Monte Carlo simulation provides no technique for evaluating the extent to which a simulated diffusion pattern corresponds to the actual one obtained from empirical observations. Brown and Moore (1969:129-130) also emphasize that:

> Relatively little progress has been made toward establishment of such a test . . . and the only valid conclusion is that the comparison of simulated and observed diffusion patterns remains as one of the most important unsolved problems in diffusion research.

Fourth, use of "an MIF type format with distance as the major controlling variable is too restrictive, both operationally and conceptually" (Brown and Moore, 1969:149). Specifically, Hagerstrand's view of the MIF assumes that the set of "probabilities of an individual communicating with other individuals at different locations is the same for all senders of messages"

(Brown and Moore, 1969:133). Even though this assumption is generally accepted, it is questionable on two counts. On the one hand, if the assumption is a model of interpersonal communication in the real world, there is yet a significant procedural question: What are the empirical data that would provide a suitable substitute for the communication network? Brown and Moore (1969:133) propose that the most appropriate data for estimating the (probabilities) that define an MIF would be supplied by "a large representative sample of day-to-day personal contacts relevant to the diffusion process being studied, using diary or repeated interview methods for collection." Whether more readiliy accessible and less costly data, e.g., distances traveled to obtain inputs, would adequately define networks of interaction has yet to be demonstrated.

On the other hand, if the assumption is not valid, then the question arises of how the set of probabilities of an individual communicating with other individuals differs from one individual or group of individuals to the next. As Brown and Moore (1969:139) state, interaction cannot be viewed solely in a spatial context; thus, "interaction is a function of a number of attributes, other than intervening distance characterizing each pair of interacting nodes." For example, in a study of diffusion in a Colombian village, Stanfield, *et al*. (1965b) found that cliques form which have much higher probabilities of within-clique than between-clique communication. Similarly, messages are more likely to be passed between so-called opinion leaders and followers than among followers. Consequently, "the probability of interaction should be specified as a function of several variables and should be computed separately for each pair of nodes" (Brown and Moore, 1969:135).

Brown and Moore (1969:137) have suggested that one possible solution would be to explore whether Monte Carlo simulation can be modified to permit the set of probabilities of communication between adopters and potential adopters to vary rather than simply assuming that the same geographical (spatial) distance bias exists for all adopters.[8] Moreover, the actual probability of communication can be more accurately estimated if the researcher is able to measure various other types of bias (e.g., economic distance bias, island model bias, acquaintance circle bias, reflexive or reciprocity bias, and forced field or popularity bias), and incorporate the resultant data into a less restrictive format of the Monte Carlo simulation approach. For example, Monte Carlo simulation would be considerably strengthened by incorporating "social distance measures," as well as physical distance in defining the spatial representation of...communication networks" (Brown and Moore, 1969:149). Also, specification of the frequency and duration of message sending by individuals as well as the characteristics of those who send information would significantly contribute to the modeling of communication networks. This latter set of variables has been extensively studied by many sociologists and communication specialists (cmpr. Rogers and Shoemaker, 1971) and is more closely examined in Chapter IV.

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[8] As an example, Tornqvist (1967:222) found in a study of the diffusion of television ownership in Sweden that:

> ...the probability of contact between different households did not depend on the physical distance between them. The information was spread in a complicated network of social relationships which we were unable to survey . . . we assume in conclusion that the factor of distance is more or less inoperative in a small region (Tornqvist, 1967:222; as cited in Brown and Moore, 1969:145).

Fifth, Brown and Lentnek (1973) point out that many researchers studying diffusion have tended to emphasize the acquiring of information about an innovation rather than the acquiring of the innovation itself. Brown (1963:2-3) notes in this regard that:

> ...geographic research on the diffusion of innovation has viewed adoption solely as the outcome of a process of learning or persuasion, i.e., adoption arises when a non-adopter acquires sufficient knowledge about an innovation to be convinced of its merits. This is in accord with the research of other social science disciplines, which have also tended to view innovation adoption and diffusion as an information gaining process. However...the gaining of information is seen to be not a necessary and sufficient condition. Acquisition of the innovation itself must also be considered since the spatial pattern of availability of the innovation to potential adopters may be quite invariant with the spatial pattern of the availability of information. Furthermore, the spread of certain innovations to a particular locality is primarily a result of marketing decisions by distributors of the innovation and shopping behavior of potential adopters, so that the availability of information on the innovation follows the availability of the good in the market.

Accordingly, research on diffusion, particularly if Monte Carlo simulation is used, should take into account "the distribution network of propagators of an innovation" and "the shopping trip behavior of potential adopters" (Brown and Moore, 1969:150). Another factor which should be considered is the distribution policies and activities of an innovation's propagators, "since it is necessary to know whether a market utilized by the potential adopter is one chosen as a distribution point by the propagator" (Brown, 1967:192). In support of Brown's argument, it is interesting to note that Griliches' (1957:507) study of the diffusion of hybrid corn in the United States concluded that:

> The date at which adaptable hybrids become available in an area is viewed as the result of seed producers ranking different areas according to the expected profitability of entry and deciding their actions on this basis. The relative profitability of entry into an area will depend on the size of the eventual market in that area, marketing cost, the cost of innovating for that area, and...the expected rate of acceptance.

By relating Griliches' conclusion to Brown's argument, expected profit is seen to be an important factor in the decision making of all self-interested propagators of an innovation. And, of the factors related to expected profit, "the size of the eventual market" is basic. Farmers residing in areas where an innovation is not distributed "will have less opportunity to purchase the innovation and less contact with distributors of the innovation who are themselves persuasive agents" (Brown, 1967:193). Thus, as Brown (1967:192-193) argues, studies of spatial diffusion should take into account two distinct and necessary subprocesses:

> The first is gaining effective information about the innovation which may result from interpersonal communication, communication through the mass media, or by exposure to the innovation at the distribution center.... The second subprocess is acquiring the innovation, which occurs when an individual who has gained effective information about the innovation journeys to a distribution center which contains the innovation.

Sixth, these various observations reflect a growing recognition of the need to take market and infrastructure as well as information factors into account in studying the diffusion of an innovation (cmpr. Brown, 1975; Byrnes, 1972; Brown and Brown, n.d.; Schneider, *et al.*, n.d.). For example, in a study of the diffusion of commercial dairying in Mexico, Brown and Lentnek (1973) divided their study's variables into two classes: situation-related and site-related variables. As Brown and Lentnek (1973:274) observe:

> Geographers have examined diffusion from a spatial point of view and have tended to emphasize situation factors in explaining differences in adoption times from place to place; others, principally sociologists and anthropologists, have given emphasis to site factors.

Here, "situation" refers to those characteristics of an individual or place that derive from its location relative to other locations (e.g., nearness or accessibility) and explain differences in time of adoption from place to place. In contrast, "site" refers to the characteristics of an individual or place that are not locationally derived (e.g., age, education, literacy, and income). The latter emphasis on "site" factors is more prevalent in studies of diffusion through time at the microscale level, i.e., within a relatively small spatial area such as a community (e.g., a village) or a highly localized rural area (e.g., a district).[9]

Seventh, the renewed emphasis being placed on infrastructure and market (or situation) factors as compared to the earlier emphasis on information (or site) factors has paralleled but not incorporated any of the concepts, measurement techniques, or analytical procedures used in studying differentiation and centrality in the macrosociological work of Young (1966) and others (e.g., Conning, 1971; Durston, 1970; Fujimoto, 1965; Spencer, 1973; Young, 1977; Young and Young, 1973; Young and MacCannell, 1967; and Young, *et al.*, 1968). The concept of differentiation is defined as "organizational change toward greater diversity of structure and function within the social system" or as "the degree to which a social system has been successful in *incorporating new information into the social system*" (Spencer, 1973:61). On the other hand, centrality is defined as "a community's position relative to other communities in the total configuration of intercommunicative paths" (Young, 1966:47).

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[9] Rather than using Monte Carlo simulation, Brown and Lentnek (1973) used a combination of principle-components analysis, discriminant analysis and stepwise regression to analyze their data.

The study carried out by Bertoli and Young (1975) on the relationship between adoption and various structural dimensions (e.g., differentiation) in a rural area of Peru is highly relevant to this section's focus on methodologies dealing with spatial distance as a determining factor in explaining the extent to which an innovation has diffused in a specific geographical region. Relying on a key informant in each of 71 districts in the state of Puno to supply information on whether at least one farmer in the district had adopted each of a number of farm practices (e.g., use of chemical fertilizer), Bertoli and Young found that their data formed a satisfactory Guttman scale (table 2) of village-level adoption of farm practices (cmpr. Byrnes, 1980). The data on the study's independent variables were then submitted to a factor analysis and three factors were identified as significant: lakeside proximity, institutional differentiation, and distance to capital cities. A multiple regression analysis of the Guttman scale of agricultural innovation was then made by use of the three identified factors as predictors (independent variables). The analysis showed that the latter two factors were statistically significant even when lakeside proximity, a factor reflecting ecological advantage, was controlled.

Bertoli and Young (1975:29) conclude "that structural dimensions of intermediate social systems, in this case Peruvian districts, are significant predictors of the level of agricultural innovation." As compared with Monte Carlo simulation, the research approach used by Bertoli and Young provides an alternative demonstration of the influence on agricultural practice adoption of such situation-related variables (e.g., differentiation and centrality) as are included in the general infrastructure and market categories. Moreover, in focusing on the pattern of institutional developments, Bertoli and Young (1975) provide a perspective on the process of an innovation's spatial diffusion that is complementary to that provided by Monte Carlo simulation as used by Hagerstrand. To this writer's knowledge, however, no researcher has yet attempted to integrate the two distinct yet

Table 2. Farm Practices Scale for Non-Hacienda Agriculture in 71 Districts of Puno, Peru, 1970 (Bertoli and Young, 1975)

Scale Step	Item	Percent Discriminated	Errors
1	Foot plow and/or barnyard manure used (haciendas excluded)	96	2
2	At least one farmer uses oxen-drawn wooden plow with a metal point	62	11
3	Buys seed especially for sowing	52	7
4	Uses pesticides on the plants	46	8
5	Uses chemical fertilizer	42	8
6	Disinfects the seeds	39	11
7	Plows with a tractor	28	8
8	Disinfects the soil	20	3
9	Uses guano from the islands for fertilizer	13	2

Coefficient of scalability = .63.

complementary approaches reflected in the work of Bertoli and Young (1975) and Monte Carlo simulation (e.g., Garst, 1972).[10]

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[10] In a study of predictors of adoption of improved agricultural practices in Togo, west Africa, Francis (1971) found that community differentiation did not correlate highly with adoption. Variables affecting these results are discussed by Francis (1971:105-107; cmpr. Weldon, 1968). On the other hand, as Whiting, et al. (1968:31) report in a study on "Success and Failure of Agricultural Programs in 76 Minas Gerais Communities" in Brazil, the analyzed governmental change agency was most successful in those communities which were "more structurally differentiated in terms of the organization of formal institutional groups." Examples of other studies which examine the relationship between differentiation and adoption of new agricultural production technology are reported by Mbithi (1971), Alao (1971), and Koppel (1978).

CHAPTER III

ECONOMIC APPROACHES TO DIFFUSION RESEARCH

Economic approaches to diffusion research set forth the hypothesis that profit from use of an innovation is a key variable in determining the rate of diffusion of the innovation and the intensity of its use by adopters. Stated somewhat differently, profit is believed to be a key variable in persuading farmers to adopt an innovation and to increase its use. While interest in the "profit hypothesis" has not been confined to any one discipline, the principal contributions to the empirical testing of this hypothesis have been made by economists. This section reviews one of these contributions, namely, logistic curve analysis and, in so doing, some of the major research studies based on this research approach or variations thereof.[11]

LOGISTIC CURVE ANALYSIS

Studies using logistic curve analysis have represented the diffusion of an innovation by an S-shaped curve (see figure 1) which is usually specified as a logistic curve, having the following mathematical expression:

$$p = \frac{P}{1 + e^{-(a + bt)}}$$

where:

p = the percentage of potential users who have already adopted the innovation;
P = the point at which all potential adopters have adopted the innovation (this point is also referred to as the asymptotic ceiling or equilibrium value of p);
t = time;
a = the constant of integration which positions or locates the curve on the time scale (abscissa) and defines the temporal starting point in the diffusion process; and
b = the rate of diffusion coefficient, that is, the rate at which potential users adopt the innovation.

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[11] The reader may wish to pursue other related areas of the economics literature which do not focus specifically on adoption or diffusion but which have theoretical and/or empirical relevance to this area of research (cmpr. Scobie and Franklin, 1977).

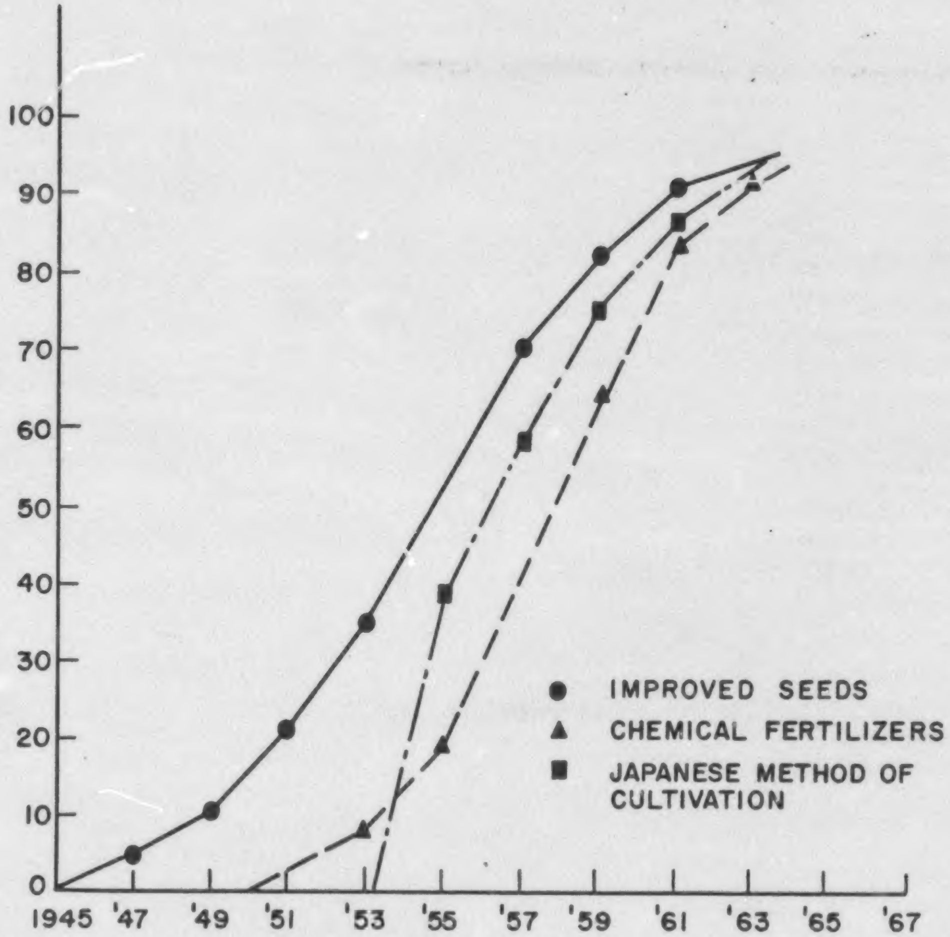

Figure 1. Percent of Farmers Who Have Adopted Each of Three Innovations at Various Points in Time in Two Villages of India (Shetty, 1966:194)

Thus, b indicates the speed with which the innovation diffuses toward the asymptotic ceiling P.

As illustrated by figure 1, the adoption of an innovation by potential users increases at an accelerating rate throughout the first half of the diffusion process and then increases at a decelerating rate during the second half of the process. While diffusion studies employing logistic curve analysis vary in the emphasis placed on studying the determinants of a and P, there is little variance with respect to identifying and estimating the relative importance of the determinants of b.

Although not carried out in one of the developing countries, the classic study employing logistic curve analysis was Griliches' (1957; 1960) study of the factors determining cross-sectional variation between regions or crop-reporting districts in the United States in the rate of growth of acreage planted to hybrid corn.[12] When Griliches fitted the logistic curve to available time series data for each region or crop reporting district, p represented the percentage of acres planted to hybrid corn, and P represented the ceiling value (referred to by Griliches as K).[13] The parameters of the logistic curve were estimated in the following manner. First, Griliches transformed the logistic function into a linear equation in a and b. By performing a few algebraic manipulations on the logistic function, one obtains a linear transformation, $\log_e [p/(P-p)] = a + bt$, enabling one to estimate the logistic function's parameters directly by least squares regression. Following this procedure, Griliches estimated the logistic function's parameters (a, b, P) for 132 crop-reporting districts, thereby reducing a large mass of data to three sets of variables--origins (a), slopes (b), and ceilings (P). Griliches then accounted for variation in the date of origin (a) in terms of supply factors affecting the availability of hybrid corn in a particular area; variation in the slopes (b) in terms of "factors affecting the rate of acceptance by farmers" (Griliches, 1957:505-506); and variation in ceilings (P) in terms of "demand factors affecting the long run equilibrium position" (Griliches, 1957:506).

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[12] For an empirical application of logistic curve analysis in a study of technological change in a developing country, see Martinez's (1973) study of the growth in corn acreage planted with hybrid corn in Argentina.

[13] "The value of K, the ceiling, was estimated crudely by plotting the percentage planted to hybrid seed on logistic graph paper and varying K until the resulting graph approximated a straight line. After adjusting for differences in K, the logistic was fitted to the data covering approximately the transition from 5% to 95% of the ceiling. The observations below 5% and above 95% of the ceiling value were discarded because they are liable to very large percentage errors and would have had very little weight anyway in any reasonable weighting schemes" (Griliches, 1957:504).

The Supply of an Innovation

Griliches considered adapted hybrid corn to have become available in a particular area as of the year in which farmers in that area began to plant 10% of total (or ceiling) corn acreage with hybrid corn. Griliches (1957:507) hypothesized that adapted hybrid corn became available as:

> ...the result of seed producers ranking different areas according to the expected profitability of entry and deciding their actions on this basis. The relative profitability of entry into an area will depend on the size of the eventual market in that area, marketing costs, the cost of innovating for that area, and the expected rate of acceptance.

As an estimate of market size or density (X_1), Griliches multiplied (1) the average corn acreage in an area at the date of entry by (2) the estimated ceiling P (i.e., the fraction of the corn acreage that would "ultimately" be planted with hybrid seed), and divided this value ("1" x "2") by (3) the total land in farms, thereby placing differentially sized districts on a comparable basis. To measure marketing costs (X_2), he used the substitute variable "average size of sale" which he measured by the average corn acres per farm. Use of this measure was based on the idea that market costs would be lower where the average size of a sale is larger. In view of the considerable differences between farms in the developing countries with respect to the costs of access to markets, Griliches' (1957:510) description of the differences in marketing practices between the Corn Belt and the South merits quotation here:

> The importance of marketing cost is underscored by the striking differences in marketing methods of hybrid seed in different parts of the country. While almost 90 percent of all the seed in the Corn Belt is sold by individual salesmen who call on each farmer, almost all of the seed in the South is sold through stores where the farmer must come and get it. The small size of the

> corn acreage per farm, the relative isolation of the small farm, and the large proportion of corn on noncommercial farms make the type of marketing used in the Corn Belt prohibitively expensive in the South. The cost of selling a given amount of seed is quite different in various parts of the country, as many more farmers have to be reached in one area than in another.

Assuming that producers had been able to predict reasonably well the rate of acceptance, Griliches used the estimated slope coefficient (b) as a measure of the expected rate of acceptance (X_3). Similarly, to approximate a measure of the cost of innovation for an area, Griliches used a variable "Corn Beltiness" (X_4), defined as the number of Corn Belt inbred lines in the pedigrees of the recommended hybrids available for that area. Here Griliches reasoned that the higher the value of this index (X_4) for a particular area, the lower the cost of innovation for that area.

Griliches found that the set of estimated origins correlated significantly with each of the four variables and the signs were as predicted.

The Rate of Acceptance

In contrast to explaining the origin (a) of the logistic curve in terms of changes in the supply of an innovation, Griliches explained the rate of diffusion (b) in terms of variables that determine the demand for an innovation. He hypothesized that variation in the rates of acceptance of hybrid corn (i.e., variation in b) is a function of differences in the profitability of the changeover from open-pollinated to hybrid seed. This hypothesis is based on the proposition that:

> ...the larger the stimulus the faster is the rate of adjustment to it. Also, in a world of imperfect knowledge, it takes time to realize that things have in fact changed. The larger the shift the faster will entrepreneurs become aware of it, "find it out," and hence they will react more quickly to larger shifts (Griliches, 1957:516).

Owing to deficiencies in data, Griliches used, as a substitute variable for profitability, "the superiority of hybrids over open-pollinated varieties," measured by the average increase in yields in bushels per acre (X_5) and the long run average prehybrid yield of corn (X_6). After adjustment of the b values for differences in the ceiling (P), the coefficients for X_5 and X_6 were found to be statistically significant in both linear and log regressions on the dependent variable (the rate of acceptance as measured by the slope b).

The Ceiling Level of Use

Griliches hypothesized that, in the long-run, the percentage of corn acreage which will be planted with hybrid seed is a function of the same profit variables that were used in explaining variation in rates of acceptance. Having made some adjustments in the data to take into account that there is a ceiling of 100% to the possible variation in P, Griliches again used the logistic function, with the dependent variable specified as logit $P = \log_e[P/(1-P)]$. The independent variables used, the average corn acres per farm (X_3) and prehybrid yields (X_6), were found to explain a substantial proportion of the variation in the long-run ceiling or equilibrium level of hybrid seed use.

While Griliches (1957:521) suggests that "trends in the use of fertilizer" may be quite similar to those which he observed in the case of hybrid corn, his study of the demand for fertilizer (Griliches, 1958) surprisingly makes no reference to his earlier study of the diffusion of hybrid corn (Griliches, 1957). However, from the conclusions reached by Griliches (1957), one would expect that changes in fertilizer use are largely explained by the profit derived from using fertilizer. Of course, the source of an innovation's profit may vary from one innovation to the next. For example, the source of profit in Griliches' (1957) study with hybrid corn was found to lie in the increased yield associated with use of the hybrid varieties, whereas the source of profit in Griliches' (1958:591) study of demand for fertilizer was found to lie in the declining "real" price of fertilizer--"fertilizer use is a function of...the price paid for fertilizer relative to the prices received for farm products," assuming that the change in usage is not instantaneous.

To test this hypothesis, Griliches (1958) employed a dynamic adjustment model which included three independent variables: (1) a "lagged dependent variable" (the quantity of fertilizer used in the preceding time period) to estimate the quantity that will be used in present season, (2) the short-run and long-run price elasticities of demand for fertilizer, and (3) the rate of adjustment over time in the quantity of fertilizer used as a function of changes in prices and other variables. The "lagged dependent variable" is included in view of the hypothesis:

> ...that an adjustment to a change in prices or to a change in any of the other independent variables takes time.... . . . ...while a substantial reduction in the real price of fertilizer may be followed by an immediate increase in use by farmers already using fertilizer, this change may also make fertilizer use profitable to a large number of farmers who had never used it before and are unfamiliar with its technology. There will be a learning process involved for new fertilizer users and for others with new fertilizer uses. This process will take time and will persist only if the price change persists for a long enough period (Griliches, 1958:596-597).

Thus, Griliches (1958:591) argued that changes in the overall quantity of fertilizer used may be explained as a function of the "real" price of fertilizer, assuming that adjustment will be spread over more than 1 year.

On the basis of a regression analysis of his data, Griliches (1958:604) concluded that most of the variation in fertilizer consumption is explained by changing relative prices, "without either invoking or even mentioning 'technological change.'" While Griliches conceded that many Midwestern farmers never used fertilizer and had little knowledge about fertilizer use before World War II, he emphasized that considerable research on fertilizer was carried out after the war and that information about fertilizer use had been disseminated by colleges, fertilizer companies, and others. However, Griliches interpreted or explained these developments largely in economic terms; specifically, that they resulted more from a substantial fall in the real price of fertilizer than from some independent causal factor.

In short, Griliches' (1958:605) position may be summarized as follows: "If an activity becomes profitable, there will be money to be made in supplying 'knowledge' about it, and 'knowledge' will be produced." Accordingly, Griliches' (1958:605) argument "is not that there was no learning process involved in effecting...large increases in fertilizer consumption, only that the process should not be treated as exogenous. This learning process can be viewed largely as the result of changing relative price...."[14]

It is worth noting that the theoretical viewpoint expressed by Griliches (1958) closely parallels the induced technical change model proposed by Hayami and Ruttan (1971). This model is based on the assumption that the key to early economic development in the rural areas of the developing countries lies in achievement of rapid technical change which leads to increased productivity in agriculture. However, the likelihood of such change is reduced by the highly location-specific character of agricultural technology and by the limits which such specification places on the agronomic feasibility of transferring such technology from areas of high to areas of low productivity (cmpr. Jennings, 1971). Thus Ruttan (1975:12) argues that:

> A necessary condition for sustained productivity growth in agriculture is the institutionalization of experiment stations capable of producing a continuous stream of ecologically adapted and economically efficient technology consistent with resource endowments and relative factor prices for each commodity of economic significance in each agricultural region.

Where experiment stations exist and are oriented toward reducing the constraints imposed by the available resources and the relative prices of the various inputs, their research will be directed toward developing technology that will encourage the substitution of relatively abundant (hence cheap) factors for relatively scarce (hence expensive) factors. Thus, constraints imposed by an inelastic supply of land can be compensated by advances in biological and chemical technology. Similarly, constraints imposed by an inelastic supply of labor can be offset by advances in mechanical technology.[15]

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14. The reader interested in a more detailed discussion of the fertilizer demand literature is referred to the following review articles: Timmer (1974), Mukhopadhyay (1975), Dalrymple (1975), and Shields (1976). This literature provides additional empirical support for the profitability hypothesis.

15. Additional work in the area of "induced innovation" is reported in Ruttan (1977b), Grabowski (1979), Pineiro, et al. (1979), Trigo (1979), and Trigo, et al. (1980). Kearl (1976) compares the "Induced Innovation Model" with the "Diffusion Model" and the "Package Programs Model."

A variation on logistic curve analysis was used by Mansfield (1961) to study the "rate of imitation" in the adoption of 12 innovations by firms in the brewing, coal, steel, and railroad industries in the United States. Using analytical procedures similar to those employed by Griliches (1957), Mansfield found that the number of firms having introduced an innovation, if plotted against time, approximates a logistic function and that the rate of imitation in a particular industry is higher for innovations which are more profitable and require relatively small investments. In contrast to Griliches' (1957) study which demonstrated the impact of profit on the increase in hybrid corn acreage, Mansfield (1961) directly tested the profit hypothesis with data on the actual adoption decisions of individual firms. Additionally, while Griliches' (1957) study was limited to the analysis of only one innovation, Mansfield's (1961) study focused on adoption decisions regarding 12 innovations by firms in four industries.

In contrast to his study of the "rate of imitation" (Mansfield, 1961), wherein the profit hypothesis was tested on data describing variation among innovations in the rates of interfirm diffusion, Mansfield (1963) also tested the profit hypothesis on data describing variation among firms in the rates of intrafirm diffusion of a single innovation, namely, the diesel locomotive. The rate of intrafirm diffusion was measured as the rate at which particular railroads, once they had begun to use diesel locomotives, increased their stock of diesel locomotives from 10% to 90% of their total locomotive stock. As in the case of Mansfield's (1961) study of the rate of interfirm diffusion, Mansfield (1963) again found that his data on the rate of intrafirm diffusion were represented reasonably well by a logistic function. Mansfield (1963) also hypothesized that the variation among firms in the rates of intrafirm diffusion would be directly related to a profit variable which was measured as the rate of return a firm could obtain by adding a diesel locomotive. An ordinary least squares regression analysis revealed that the sign of the coefficient for the profitability variable was in the expected direction and statistically significant. Additionally, the analysis showed that the rate of intrafirm diffusion was also significantly correlated in the expected direction with a variable used as a substitute or indirect measure of risk, namely, for a specific firm i, the time interval separating the year in which the first firm began using diesel locomotive from the year in which the i_{th} firm began using the diesel locomotive. Finally, the analysis revealed that the signs of the coefficients for two additional variables, liquidity and size of firm, were also in the expected direction, although only the liquidity variable was found to be statistically significant.

Comparing the analyses he reported in 1961 with those he reported in 1963, Mansfield (1963:358) notes that the models used to explain variation in the rates of intrafirm diffusion are basically quite similar in structure and content. The similarity of the two models, argues Mansfield (1963:358), suggests that there may be considerable similarities between the two diffusion processes:

> The profitability of an investment opportunity acts as a stimulus, the intensity of which seems to govern quite closely a firm's speed of response. In terms of the diffusion process, it governs both how rapidly a firm begins using an innovation and how rapidly [the firm] substitutes it for older methods.

The studies by Griliches (1957) and Mansfield (1961, 1963) demonstrate the use of logistic curve analysis in the study of the diffusion of innovations in American agriculture and industry. At least two publications (Aklilu, 1976 and Shetty, 1966), however, report the use of logistic curve analysis in the study of the diffusion of innovations in agricultural production technology in the developing countries. These studies are now briefly reviewed.

Similar in design to Griliches' (1957) study of variation between crop-reporting districts in the rate of growth of area planted to hybrid corn in the United States, Aklilu's (1976) study of variation in the rate of growth of fertilized area in Ethiopia's Minimum Package Programme Areas (MPPAs) provides some of the best evidence currently available regarding the factors that determine the diffusion of fertilizer use in a developing country. Using data on the percentage of area fertilized in each of 20 MPPAs at each of four points in time from 1971-1974, Aklilu estimated the slope coefficient (b) of the logistic curve for each of the MPPAs. To explain the variation between MPPAs in b, Aklilu suggested the following explanatory variables:

1. profitability (measured by the market value of the absolute difference between the fertilized and unfertilized per-hectare crop yields);
2. absolute variability of the fertilized yield (measured by the coefficient of variation of the fertilized yield);

3. magnitude of profit (measured by average farm size); and

4. availability of information (measured by the number of extension personnel within each MPPA).

A regression of the 20 b values on these four variables revealed only the profitability variable to be statistically significant, explaining 25% of the variation.

In view of the small size of his sample, Aklilu checked these results by an alternative model which pooled the cross-section and time-series data in a single regression model to estimate the rates of diffusion and the parameters of the explanatory variables simultaneously. This model is derived by substituting $\alpha + \beta X_{1i} + \ldots + \varepsilon$ for b in

$$\text{Log } p_i/P - p_i = a + b_i t + \ldots + \varepsilon_i .$$

This gives a single regression model:

$$\text{Log } p_i/P - p_i = a_i + \alpha t + \beta X_i t + \ldots + \varepsilon_i$$

where:

t = time and varies from 1 to 4,
X = the set of four explanatory variables used in the original logistic model and each variable is multiplied by time, and
i = a specific MPPA and varies from 1 to 20.

This gives a regression that is based on 80 observations. Thus, the pooled regression model allows greater flexibility in that many explanatory variables can be investigated at the same time due to the large number of degrees of freedom obtained by pooling the data.

Following this procedure, Aklilu estimated the following regression model:

$$\text{Log } p_i/P - p_i = -5.5415 + .0013X_1 - .6635X_2 + .0687X_3$$

where:

X_1 = profitability
X_2 = absolute variability
X_3 = availability of information

This equation explained 57% of the variance and each of these estimated parameters was statistically significant with profitability, availability of information, and absolute variability explaining 32, 20, and 5% of the variance, respectively. In addition to profitability which continues to be an important explanatory factor, absolute variability was found to have the expected negative sign, indicating that the rate of growth in fertilized area was lower in MPPAs where the variation in the yield of the fertilized crop exceeds that of the unfertilized crops. Finally, the availability of information variable also appears as important. Moreover, Aklilu found that when this factor is introduced with the other three (including time) explanatory variables, the coefficient for the time variable fails to be statistically significant. This indicates that a positive change in the availability of information will reduce the "wait and see" tendency that is associated with the time variable. Although the farm size variable was not statistically significant, it is interesting to note that this variable's coefficient had a negative sign, which indicates that fertilizer is more likely to be used as land becomes scarcer.

As a further check on these results, Aklilu ran linear, semilog, and double log regressions of the three statistically significant independent variables on the percentage of area fertilized in 1971, the percentage of area fertilized in 1974, and the difference in the percentage of area fertilized between 1971 and 1974. Since fertilizer was being used for the first time in 1971 and the effect of variables, such as profitability and variability, were not yet known, it is not surprising that Aklilu found no relationship between any of the variables and the percentage of area fertilized in 1971. However, when the percentage of area fertilized between 1971 and 1974 becomes the dependent variable, both profitability and availability of information become statistically significant. The double log equation enables one to interpret the effect of the independent variables in terms of elasticities. The profitability variable explains 57% of the variation in increased area fertilized between 1971 and 1974, while the availability of information variable explains 300% of this variation. While profitability and availability of information were found to be important in both the pooled regression and "difference in percentage of area fertilized" models, the finding that variability was not statistically significant in the linear, semi-log, and double log versions of the latter model suggests, at least in the Ethiopian case, that caution is needed in interpreting the effect of the variability of fertilized yield on adoption of fertilizer use.

Finally, Aklilu divided the 20 MPPAs into three groups, according to the predicted rates of growth (see table 3). Analyses of variance for the mean rates of growth in area fertilized and the mean percentages of area fertilized in 1974 indicated that the three groups are significantly different from one another. As evidenced in table 3, the return from using fertilizer (benefit:cost ratio) is highest for the MPPAs in Group 1, the MPPAs having the fastest rate of growth in the percentage of area fertilized. Comparing the MPPAs in the groups with the fastest (e.g., Jimma MPPA in Group 1) and slowest (e.g., Bako MPPA in Group 3) rates of growth, Aklilu (1976:83) notes that "the assertions of previous researchers that a benefit:cost ratio of at least 2 is necessary for small farmers to accept an innovation finds support in our study."[16] Table 3 also demonstrates that the different rates of growth are also correlated with the availability of information (extension personnel) and variability (both absolute and relative) of the fertilized yield, although only the former variable is statistically significant.

In focusing on the rate of growth in the area fertilized in each of the 20 MPPAs, Aklilu's (1976) logistic curve analyses only indirectly focus on the rate of diffusion of fertilizer use, i.e., the rate of growth in the percentage of adopters of fertilizer use per time period.[17] This latter phenomenon, however, was studied in Shetty's (1966) investigation of the factors determining the diffusion of fertilizer use in two villages in India. Drawing on data (table 4 and figure 1) collected in a survey of farmers in the two villages, Shetty used least squares regression to estimate the parameters of the logistic curve for each of three innovations (table 5) and for each year the expected percentage of farmers adopting each innovation (table 6). However, having pooled his data in order to estimate a rate of diffusion (or slope) parameter (b) for each innovation and having data on only three innovations, Shetty was not able to attempt to explain either variation between districts (or villages) in the rate of interfirm (interfarm) diffusion, or variation between innovations in the rate of interfirm (interfarm)

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[16] The reader interested in a more detailed discussion and critique of the idea that a benefit:cost ratio of 2 is necessary for small farmers to adopt an innovation is referred to Mudahar's (1977) discussion of "Rationality, Fertilization, and Convergence to Marginalism" in his paper on the economics of food, fertilizer, and public policy in the developing world.

[17] Aklilu (1976), however, does focus on differences between farmers in the time of initial use of fertilizer in a later section of his study. There he uses a factor analysis model to explain variation between farmers in the time of initial use of fertilizer and in the level of adoption of fertilizer use. This study is discussed in Chapter V.

Table 3. Mean Values of the Predicted Rates of Growth in Area Fertilized in Three Groups in Ethiopia's MPPAs and the Explanatory Variables (Adapted from Aklilu, 1976:84)

Variable	Group I	Group II	Group III
Predicted rate of growth in area fertilized	1.23[b]	.77	.47[b]
% area fert. in 1971	1.69	.50	.65
% area fert. in 1974	24.50[b]	6.50	2.27[b]
Benefit ($/hectare)	269.59[b]	67.46	40.55[b]
Cost ($/hectare)	38.00	38.00	38.00
Benefit:cost ratio	7.09[b]	1.78	1.07[b]
Relative variability	-.19[a]	.02	.12[a]
Absolute variability	.29	.38	.46
Extension personnel	11.30[b]	9.25	7.25[a]
Farm size (hectares)	4.49	5.73	4.96
Number of MPPAs	5	7	8

a. Mean significantly different from each other at .05 level (only the significance of the difference between I and III is given here).
b. Mean significantly different from each other at .01 level.

Table 4. Distribution of Adopters in Two Villages of India According to Time Interval Between First Year in Which Farmers Adopted and Year in Which Subsequent Farmers Adopted (Shetty, 1966:192)

Time Interval	Improved Seeds		Chemical Fertilizers		Japanese Method of Paddy Cultivation	
	Number	Percent	Number	Percent	Number	Percent
0-2	11	6	5	4	25	31
3-4	10	5	11	9	21	26
5-7	27	13	37	28	26	32
8-10	61	30	60	46	8	10
11-13	59	29	14	11	1	1
14-16	26	13	3	2	-	-
17 and above	7	4	-	-	-	-
Total	201	100	130	100	81	100

Table 5. Least Squares Regression Estimates of Parameters of Logistic Curve Fitted to Observed Data for Three Innovations in Two Villages of India (Shetty, 1966:194)

Innovations	a	b	X^2 (Chi-Square)[a] Goodness of Fit
1. Improved seeds	-3.19	+0.37	4.09[b] (33.41)
2. Chemical fertilizers	-3.44	+0.51	4.64[b] (27.69)
3. Japanese method of paddy cultivation	-0.83	+0.40	7.42[b] (23.21)

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a. Figures in brackets represent the tabular value of X^2 at .01 level.

b. Logistic curve gives a good fit as the divergence between expected values and observed values is not significant at 1% level.

Table 6. Cumulative Observed and Expected Percentages of Farmers Adopting an Innovation Year by Year with Logistic Curve Fitted to Observed Data for Three Innovations in Two Villages of India (Shetty, 1966:193)

	Improved Seeds		Chemical Fertilizers		Japanese Method of Paddy Cultivation	
Year	Observed	Expected	Observed	Expected	Observed	Expected
1946	3.48	3.95				
1947	5.47	5.62				
1948	7.96	7.94				
1949	10.45	11.12				
1950	14.43	15.31				
1951	17.91	20.75	2.31	3.11		
1952	23.88	27.47	3.85	5.07		
1953	31.84	35.46	6.93	8.16		
1954	41.79	44.25	12.32	12.90	22.22	30.40
1955	54.23	53.48	20.01	19.76	30.86	39.37
1956	65.18	62.50	29.24	29.16	41.98	49.26
1957	74.63	70.42	40.78	40.49	56.79	59.17
1958	83.59	77.52	56.93	53.19	74.07	68.49
1959	90.06	83.33	71.54	65.36	82.72	76.34
1960	93.54	87.72	86.15	75.76	88.89	82.65
1961	96.52	91.74	93.84	84.03	91.36	87.72
1962	98.51	93.46	96.15	90.09	96.50	91.74
1963	100.00	95.24	97.69	93.46	98.77	94.34
1964			100.00	96.15	100.00	96.15
	$t_{1945} = 0$		$t_{1950} = 0$		$t_{1953} = 0$	
	N = 201		N = 130		N = 81	

diffusion. Consequently, Shetty was limited to explaining variation between farmers in the year in which the innovation was adopted by the i_{th} farmer.[18]

To explain this variation, Shetty proposed the following model:

$$\text{Log } d_{ij} = a_0 + a_1 \log S_{ij} + a_2 \log T_{ij} + a_3 \log C_{ij} + a_4 \log L_{ij} + a_5 \log A_{ij} + a_6 \log E_{ij} + a_7 \log R_{ij} + e_{ij},$$

where:

d_{ij} = the number of years the j_{th} farmer waits before beginning to use the ith innovation;

S_{ij} = the size of the j_{th} farm;

T_{ij} = the extent of tenancy on the j_{th} farm;

C_{ij} = the magnitude of the wealth position of the j_{th} farm;

L_{ij} = the liquidity of the j_{th} farm;

A_{ij} = the age of the j_{th} farmer;

E_{ij} = the education level of the j_{th} farmer;

R_{ij} = a measure of the rate of return from investment in innovation i;

e_{ij} = a random error term; and

$a_1, a_2, a_3, \ldots$ = parameters which are expected to be negative except in the case of a_2 and a_5;

a_0 = the intercept parameter which varies for each innovation.

The parameters for this model were estimated by least squares regression (table 7). In the case of the diffusion of fertilizer use, there were several significant elasticities of delay: extent of tenancy (+.0527), magnitude of the farmer's wealth position (-.1829), and the rate of return from investment in fertilizer (-.3278). Shetty (1966:198) concludes:

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[18] In focusing on the individual farmer as the unit of analysis and the time of initial fertilizer use as the dependent variable, Shetty's methodology is more similar to "innovativeness analysis" (discussed in Chapter IV) than to logistic curve analysis. However, in view of Shetty's estimation of the slope coefficient of the logistic curve of the diffusion of fertilizer use and the inclusion of a profitability variable (rate of return from investment in fertilizer), as one of his explanatory variables, Shetty's (1966) study is discussed here in relation to logistic curve analysis.

Table 7. Regression Coefficients, Standard Errors, and Multiple Coefficients of Determination for Three Innovatiors in Two Villages of India (Shetty, 1966:197)

Innovations	Constant a_0	Regression Coefficients a_1	a_2	a_3	a_4	a^5	a^6	a^7	Coefficient of Determination R^2	Number of of Observations
1	2	3	4	5	6	7	8	9	10	11
Improved seeds	1.3662	-0.2780	+0.0462	+0.0692	-0.1873[b]	+0.6262[b]	+0.3765[b]	+0.0744	0.0743[b]	201
	(1.6823)[a]	(0.1913)	(0.1172)	(0.1623)	(0.0791)	(0.2936)	(0.1497)	(0.1008)	(2.2141)	
t	0.8121	-1.4533	+0.3939	+0.4263	-2.3691	+2.1124	+2.5151	+0.7383		
Chemical fertilizers	5.0012[b]	-0.1462	+0.0527[b]	-0.1829[b]	-0.0134	-0.0502	-0.0338	-0.3278[b]	0.5233[b]	130
	(0.6928)	(0.0779)	(0.0195)	(0.0625)	(0.0239)	(0.1422)	(0.0555)	(0.0927)	(19.1288)	
t	7.2187	-1.8755	+2.7034	-2.9289	-0.5616	-0.3529	-0.6081	-3.5379		
Japanese method of paddy cultivation	6.0293[b]	-0.0346	+0.0347[b]	-0.1131[b]	+0.0105	+0.0019	-0.0252	-1.1928[b]	0.8053[b]	81
	(0.5781)	(0.0628)	(0.0160)	(0.0442)	(0.0153)	(0.1133)	(0.0412)	(0.1192)	(43.1322)	
t	10.4295	-0.5505	+2.1693	-2.5570	+0.6844	+0.0166	-0.6103	-9.9718		

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a. Figures in parentheses in columns 2 to 9 are standard errors. In column 10 figures in parentheses are estimated values of F.
b. Statistically significant at .05 level.

> The rate of diffusion tended to be faster for innovations that were more profitable. The results also strengthen our suppositions that the variations in the [farmer's] speed of response to an innovation can be explained by the differences in size of land holding, tenurial status of the farm operator, profitability of the innovation and the farm's liquidity.

Finally, Shetty (1966:198) argues that the analytical procedure which he used is helpful not only in explaining differences between innovations in the rate of interfarm diffusion but also in providing:

> ...some basis for predicting whether one farm will be quicker than another to use [a] particular innovation. The farmers who cultivate larger land holdings and who are also owners of [their] farms and have larger fixed capital with adequate liquidity are the early adopters of an innovation.

CRITIQUE OF LOGISTIC CURVE ANALYSIS

The preceding section reviewed the application of logistic curve analysis to the study of factors which Aklilu (1976) expected to be important in determining variation among Ethiopia's MPPAs in the rate of growth of area fertilized. While Shetty (1966) estimated a logistic curve of the diffusion of fertilizer use similar to the curves estimated by Aklilu, Shetty was only able, in view of the limited scope of his data, to explain variation between farmers in the time of initial use of fertilizer. In both cases, however, as in the studies conducted by Griliches (1957) and Mansfield (1961, 1963), profitability was found to be the key variable determining the rate of expansion in use of the innovations studied. Aklilu's study also highlights the influence which information availability (extension personnel) and yield variability (of fertilized crops in relation to unfertilized crops) have on the growth of area fertilized. However, Aklilu found no statistically significant relationship between the rate of growth of fertilized area and either tenancy or farm size. In contrast, Shetty found that the extent of tenancy and the magnitude of the wealth position (as measured by size of farm) were positively and negatively correlated, respectively, with the number of years a farmer waits before beginning to use fertilizer.

These "discrepancies" may in part be accounted for by differences in the nature of the agricultural situation studied, the level of the unit of analysis, or the specification and/or measurement of the dependent and independent variables. But they illustrate the difficulty of attempting to generalize, beyond the empirical findings of individual studies, regarding the impact which variables other than profitability have on the diffusion of an innovation such as fertilizer use.

Although this problem is encountered in any attempt to compare and generalize from specific diffusion studies, it is notably present in the methodology of logistic curve analysis.[19] This difficulty arises because the approach basically consists of an analysis which attempts to identify, after an innovation has already diffused to a considerable extent, what the factors are which explain why the innovation diffused more quickly in some areas than in others. Researchers, such as Griliches (1957), Mansfield (1961), Aklilu (1976), and Shetty (1966), who have employed logistic curve analysis have typically focused on the rate of diffusion of an innovation as the dependent variable which is to be explained. In such studies, the researcher selects a population in which a number of years have passed since the innovation was introduced to and first adopted by a small percentage of the potential adopters; and the cumulative percentage of adopters during this time period has reached a relatively high level before the point in time that the researcher attempts to estimate the average slope of the logistic curve. In short, the logistic curve's slope is estimated on the basis of data on the number of potential adopters who have adopted during each of a successive number of time periods (e.g., years).

However, if the cumulative percentage of adopters is still quite low only a few years after an innovation is first introduced (adopted), then there remains a large percentage of farmers who are potential adopters. Under these circumstances, the problem of estimating the average rate of diffusion (i.e., the average slope of the logistic curve) is complicated by the fact that the researcher must make a potentially unrealistic assumption about the ultimate ceiling of adoption, i.e., the maximum percentage of farmers who are likely to adopt. Although the average slope of the logistic curve can be estimated if the cumulative percentage of adoption has reached the asymptotic ceiling or if the researcher assumes a ceiling value, the literature evidences, to this writer's knowledge, no studies in which the researcher estimates the average slope in a case where the cumulative percentage of adopters has not increased above a relatively low level. Indeed, as in the case of the Puebla Project in particular and the Green Revolution in general, the available literature does evidence that agriculturalists have frequently overestimated the potential number of farmers for whom a recommended innovation is indeed improved.

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[19] Disagreement over the importance of profitability in comparison to social variables in determining the rate of diffusion of an innovation sparked a lively debate in the literature. Relevant material in this debate includes Brandner and Strauss (1959), Brandner and Kearl (1964), Griliches (1957, 1960a, 1960b, 1962), Rogers (1962:138-142), Rogers and Havens (1960), Havens and Rogers (1961), Rogers and Shoemaker (1971:161-164), and Babcock (1962).

In short, logistic curve analysis has primarily been used where the cumulative percentage of adopters has, at least in some of the areas under study, reached a relatively high level. Researchers have then proceeded to attempt to explain why the innovation diffused faster in certain areas than in others. In view of the fact that the logistic curve approach has primarily been used in analyses which include areas or cases where the cumulative percentage of adoption has already reached a relatively high level, it is not surprising that such analyses have found that the rate of diffusion of an innovation is highly correlated with the profitability of that innovation. While this finding is as one would expect, it does little to identify those constraints which, if they had been relaxed or removed when the cumulative percentage of adopters was yet relatively low (e.g., 10%), would have subsequently speeded up the rate of diffusion.

Consequently, while logistic curve analysis has consistently demonstrated the importance of profitability in determining the rate of diffusion of an innovation, this approach to diffusion research has been of limited value in providing policy-relevant information about what the likely impact on adoption would have been at any given time if one or more of the constraints operating at that time had been relaxed. If such knowledge had been available earlier and effective policies and programs implemented, then a much differently shaped diffusion curve would have resulted. In focusing on providing ex post (after the fact) explanations about why there were variations in the past in the rate of diffusion of an innovation which most farmers have already adopted, logistic curve analysis is less than satisfactory in providing the policy-relevant information required on an ex ante basis in order to design future policies and/or programs that will increase the rate of diffusion of an innovation which only a relatively small percentage of farmers have adopted to date.

ECONOMIC CONSTRAINTS TO ADOPTION

Our ability to provide generalizations about the impact of various potential constraints on adoption is limited not only if we attempt to compare various studies employing logistic curve analysis, but also if we attempt to compare specific constraints across different diffusion studies. For example, in a review of a number of studies on the diffusion of new wheat and maize varieties and fertilizer use (cmpr. Colmenares, 1975a, 1975b; Cutie, 1975; Demir, 1976; Gafsi, 1976; Gerhart, 1975; and Vyas, 1975), Perrin and Winkelmann (1976:8) conclude that farmer behavior was generally not found to be significantly or *consistently* related to the potential economic constraints that were investigated. Similarly, on the basis of a review of potential economic constraints (specifically, farm size, tenancy, labor availability, capital availability, markets and prices, and risk and uncertainty) to adoption of agricultural technology in the developing countries, Schutjer and Van Der Veen (1976:41-42) conclude:

> Each of the economic factors examined *were reported to operate as a constraint* on technology adoption *by some authors and not by others* - a result to be anticipated from a world wide review. However, *the research reported does not provide the basis for understanding the variation in results*. As a result, *the available literature does not support the development of sound generalizations regarding consistent patterns of economic constraints* facing farmers in developing nations who seek to adopt new or improved technology (emphasis added).

While their review found no consistent pattern with regard to economic constraints on adoption, Schutjer and Van Der Veen (1976:44) emphasize that

> ...the lack of a consistent pattern does not suggest that in individual attempts to introduce technology economic factors are not important. Clearly, that is not the case. Economic factors...are...found to be important in some cases. In other studies these factors are ignored or found to be not significant. The important implication of these results is not that political economic constraints can be ignored, but rather that when they are recognized, programs and policies can often be designed to overcome the potential constraint or to avoid negative implications.

The problem, of course, is in recognizing potential economic constraints far enough in advance to take them into consideration in the design of policies and programs which are intended to relax existing constraints and, thereby, to accelerate an innovation's diffusion. While there should be no confusion about whether economic constraints are important, there does seem to be considerable confusion regarding which constraints should be recognized as economic in nature. Schutjer and Van Der Veen (1976) and Perrin and Winkelmann (1976), for example, place considerable emphasis on what they identify or recognize as "economic constraints," but they provide no explanation of why other types of potentially important constraints of an agronomic or social nature are not also emphasized. Indeed, in any region, one may find that a number of constraints of various types simultaneously operate to influence or determine the pattern of an innovation's diffusion. This is illustrated in various studies which have dealt with the reasons farmers do not use fertilizer.

Williams (1968:23), for example, found that Nigerian farmers reported that they did not use fertilizer because of inaccessibility to the requisite facilities: "no money to use practice" (16%) and "materials for using practice not available" (13%). Similarly, in seeking an explanation of why a sample of Philippine farmers rejected two-thirds of the innovations which extension workers attempted to introduce, Feliciano (1964) found that 6 out of 10 farmers cited lack of availability of the necessary resources: seeds, instruments, chemicals, feeds, water, collateral or money, and time. In an earlier study also conducted in the Philippines, von Oppenfeld, et al. (1962) found that the principal reasons given by farmers for not adopting recommended innovations were lack of funds or magnitude of capital required (21%) and lack of facilities, materials, or services (20%), although another 12% cited lack of awareness or lack of confidence in results, reflecting that lack of information (awareness-knowledge) and a perception of the innovation as being unreliable were also operating as constraints to adoption. These latter factors are discussed in greater detail in subsequent sections.

Studies directed by the International Rice Research Institute (IRRI) point to a variety of agronomic, economic, and social factors as potential constraints to the adoption of a recommended technology or use of its inputs at the recommended level. An extensive study of changes in rice farming in selected areas of Asia (IRRI, 1975), for example, provided considerable support for the hypothesis that the level of input use is more closely associated with the state of the physical environment than with socio-economic factors with the exception of price which is clearly related to input use.

To obtain a better understanding of the relative importance of these various factors as potential constraints to adoption, IRRI began a research program to develop and test a methodology to identify and explain the "gap" between the yields obtained by farmers and those obtained in experimental stations (De Datta, et al., 1978; IRRI, 1977, 1979). This methodology involved experimental plots in the farmer's field to identify:

1. the maximum potential yield,
2. the yield corresponding to the farmer's input level,
3. the yield corresponding to the inclusion or withdrawal of one or more selected components (e.g., fertilizer), and
4. the relative contribution of each of the selected factors to the differences between the farmer's yield and the potential yield.

These data provided a basis for determining through economic and statistical analysis whether a higher level of inputs would increase yields and whether such higher input levels are profitable. Where profitable, farm survey data were used to determine the reasons (e.g., unavailability of inputs, lack of knowledge on the part of the farmer, etc.) farmers were not using a higher level of inputs.

A sample of the type of conclusions reached by this analysis is reported by Herdt and Wickham (1975:179-180) for the Philippines. In this case, the gap between actual and potential yields was explained by the lack of control over water and the associated problem of moisture stress (23% of the difference between actual and potential yields), available solar radiation and other factors associated with season (19%), economic factors including risk (17%), a combination of factors including year-to-year variations in weather and damage by pests and diseases (17%), and lack of availability of inputs and nonadoption of new technology (22%). The farmer who is confronted by constraints of this type finds that it is not profitable to adopt the recommended technology, that it is too risky to adopt such technology, or that it is only profitable to use the recommended technology at a level of input that is considerably less than that which has been recommended.

Data reported by Chawdhari, et al. (1965), indicate that Indian farmers perceived the lack of access to various inputs as blocking their adoption of fertilizer use. Specific reasons given by farmers for not using fertilizer were: inadequate irrigation supply (22% of all reasons given), lack of funds and high cost of fertilizer (31%), and difficulty in obtaining supplies (10%).

When fertilizer users were asked to specify the factors that prevented them from using greater quantities of fertilizer, they gave the following reasons: the size of package (nonavailability of fertilizer in less than 1-quintal lots) (100%), high cost of fertilizer (80%), and lack of funds and nonavailability of credit (20%).

In a national sample of 4,118 farmers in India from 1968/69 to 1970/71 (NCAER & FAI, 1974), the principal constraints on adoption of fertilizer use were identified as inadequacy of funds and credit (43%), inadequacy of water (39%), and fertilizer supply problems (3.5%). Similar factors (table 8) were identified as resulting in nonadoption of fertilizer use in a 1969/70 study of 38 farmers (in Baroda district) and 15 farmers (in Junagadh district) in Gujarat, India (Patel, 1973). When farmers surveyed in 1969/70 in the Punjab of Pakistan were asked to give the reasons they had reported fertilizer was "not easily available," their responses were: price too high (95%), unable to get needed fertilizer on time (75%), and transportation problems (3.4%) (Lowdermilk, 1972).

While data such as those reviewed above may provide an initial indication regarding the factors which may operate in developing countries as constraints to adoption of fertilizer use and other innovations in agricultural production technology, such data provide, at best, only a limited understanding of the relative importance of these factors. Indeed, commenting on the purported "economic constraints" which they reviewed, Schutjer and Van Der Veen (1976:46) write that

> ...economic factors...were generally assumed to directly influence the adoption decision. Thus, the general pattern of analysis was to correlate...adoption of technology with variation in...the various economic factors and to provide little if any evidence regarding the underlying basis for the correlation (emphasis added).

One possible explanation for this situation is that the so-called "economic factors" are neither "economic" nor (in terms of economic theory) related in any clear-cut fashion to the decisions which a farmer makes about the use of an innovation. However, if there is an "underlying basis" in economic theory for a relationship between the types of factors reviewed by Schutjer and Van Der Veen (1976) and the decisions which a farmer makes about use of an innovation, this basis should lie in the effect which such factors have in determining the profitability of using

Table 8. Constraints on Adoption of Fertilizer Use in a Sample of 38 Farmers (in Baroda District) and 15 Farmers (in Junagadh District) in Gujarat, India (Adapted from Patel, 1973)

Constraint	Percent	
	Baroda	Junagadh
Inadequacy of finance	28.0	28.8
Lack of irrigation	23.6	28.8
Preference for farm manure	15.6	21.9
High price of fertilizer/low prices of crops	12.4	1.4
Imperfect supply arrangement	6.7	6.9
Other	13.7	12.2
Total	100	100

the innovation. As a prominent agricultural economist writes with respect to fertilizer use: "The determining factor for the decisionmaker, the individual farmer, is...profitability" (Dalrymple, 1975a:2).

If this is the case, any one or more of the following possibilities may influence the decisions which a farmer makes about use of fertilizer: (1) the factors in question increase or decrease the profits derived from using fertilizer; (2) the factors are perceived by the farmer to increase or decrease the profitability of using fertilizer; and/or (3) the factors increase or decrease the farmer's ability to determine accurately the overall profitability of using fertilizer. It is also reasonable to assume that where such factors are operative, they will be influential in determining not only the length of time a farmer waits before deciding to use fertilizer, but also the amount he will use once he has adopted this practice.

While a subsequent discussion of "innovation attribute analysis" (see Chapter IV) deals with "profitability" and other attributes, the discussion here focuses on several variables which (in terms of their impact on the profitability of using an innovation) may appropriately be referred to as "economic constraints." The variables or factors to be examined are farm size; tenancy; labor availability; education; capital (credit) availability; water availability; and markets, prices, and infrastructure. As a preface to this discussion, it should be pointed out that there is widespread recognition that the profitability of using fertilizer depends not only on such "economic factors" or "economic constraints" as may exist but also on the physical response of a crop to fertilizer. This section is primarily concerned with assessing the potential impact of the so-called "economic factors" or "economic constraints" on adoption of fertilizer use; however, inadequate crop response to fertilizer cannot be overemphasized as a potential agronomic constraint to adoption and expanded use of fertilizer. This potential constraint is particularly important where agro-climatic and topographical differences can markedly influence yield levels.

Indeed, in summarizing studies on the diffusion of new wheat and maize varieties in Colombia (Colmenares, 1975b), El Salvador (Cutie, 1975), Turkey (Demir, 1976), Tunisia (Gafsi, 1976), Kenya (Gerhart, 1975), India (Vyas, 1975), and Mexico, Perrin and Winkelmann (1976:6) conclude that agro-climatic and topographical differences were "the most consistent [factors] in explaining why some farmers adopt new varieties and others do not." This conclusion is reinforced by studies of changes in rice farming in Asia (cmpr. Herdt and Wickham, 1975; IRRI, 1975). In light of the potential impact of agro-climatic and topographical variability on adoption, Perrin and Winkelmann (1976:8) emphasize that "it will often be difficult to identify to what extent productivity factors are affecting farmers' decisions versus differences in economic factors such as information, tenure, input and product markets, scale economies, etc."

Farm Size

Schutjer and Van Der Veen (1976:14) report that "the evidence regarding a gross correlation between farm size and technology adoption is mixed." For example, in their study of the diffusion of high-yielding varieties (HYVs) of rice in the Philippines, Liao and Barker (1969) found no significant correlation between farm size (area planted) and the adoption period in months or the percentage of area planted in new rice varieties. Castillo (1975b) and Griffin (1972) similarly found no relationship between farm size and adoption of HYVs of rice in samples of Philippine farmers. A number of adoption studies in India and Pakistan, however, report a positive relationship between farm size and early adoption of HYV technology (cmpr. Panse and Singh, 1966; Choudhary and Maharaja, 1966; Shetty, 1969b; Muthia, 1971; von Blanckenburg, 1972; and Rochin, 1972). A case in point is provided by Schluter's (1971) study of adoption of HYV technology in India.

Schluter (1971:35) reports that in 45 out of 70 areas in his sample, there was a significant positive relationship between farm size and the proportion of farmers which had adopted HYVs, although the nature of the relationship was found to vary considerably among crops and regions. As an example of the influence which the crop grown by the farmer has on adoption, a positive relationship was found to exist between farm size and adoption of HYVs to a greater extent in millet-growing regions than in paddy-growing areas. When one compares the paddy rice and millet areas, one finds that there is a greater availability of irrigation in paddy areas, and this decreases the variability in yield when traditional varieties are replaced by new varieties. Also, income per acre is much higher in paddy than in millet areas. Thus, the smaller farmer in paddy areas faces less uncertainty and risk than the smaller farmer in millet areas. In short, risk and uncertainty operate as a constraint to adoption of HYVs to a lesser extent in paddy areas and to a greater extent in millet areas, thereby explaining why the positive relationship between farm size and adoption of HYVs was evidenced to a greater extent in millet than in paddy areas.

As an example relating to the impact of regions on adoption, Schluter (1971:35) reports that the positive relationship between farm size and adoption in the paddy areas of Andhra Pradesh was less apparent than in similar areas in West Bengal; this reflects a higher proportion of irrigated land in the former. This observation is consistent with Schluter's (1971:35) general finding that "the higher the proportion of land irrigated in a region, the higher the overall level of adoption [of HYVs]." Yet "even when a very high proportion of the acreage on all farm size groups is irrigated, ...differences in the level of adoption between farm size groups persist" (Schluter, 1971:35).

Although any of a number of potentially intervening variables could possibly explain the relationship between farm size and adoption, Schluter's analyses revealed that neither irrigation (proportion of land irrigated) nor tenancy (proportion of land owned) could alone account for the relationship between farm size and adoption. Schluter's analyses, however, do tend to support an interpretation that the farmer's acreage (likely to be highly correlated with his income and wealth) "may act as a proxy variable both for the [farmer's] ability to bear uncertainty...and the amount of own funds available for the purchase of variable inputs." Also, a relatively large acreage is likely to ensure that the larger farmer will qualify and receive credit from institutional sources. Finally, while all farmers may want credit, shortage of supply, political factors or even mismanagement will influence loan disbursements, thereby, reducing the availability of credit to smaller farmers. Even if the small farmer is able to obtain credit which can be used for purchasing (adopting) an innovation, his use of such credit for adoption implies a higher cost than is faced by the large farmer who uses 'own funds' for adopting the innovation. When these various factors are taken into account--that the greater acreage, income, and wealth of the larger farmer translate into a greater ability to bear risk and uncertainty, readier access to use of "own funds," and the requisite collateral to qualify for institutional credit--it becomes clear that the larger farmer is more readily able to adopt new technology and to adopt such technology at a much earlier date than is possible for the smaller farmer.

Various studies indicate that there is a correlation between farm size and early adoption of innovations such as HYVs and fertilizer use. However, there is also evidence that, as such innovations begin to diffuse, smaller farmers may plant a larger proportion of their land area in HYVs and employ a higher level of inputs than owners of larger farms. For example, Schluter (1971) reports an inverse relationship between farm size and proportion of acreage under HYVs in India, a relationship which increased as the time after the introduction of the new varieties increased. Sharma (1973) also found the level of adoption of the total HYV package which included fertilizer use to be higher on the smaller farms in another area of India. Similarly, in a study of interfarm variation in rice production and yields in the Philippines, Van Der Veen (1975) found an inverse relationship between farm size and the amount of fertilizer and labor used per hectare. These studies illustrate the complementarity between innovations such as fertilizer use which are more labor intensive and the smaller farm on which availability of labor per hectare is typically greater. In other words, as farm size increases, the availability of labor becomes more of a constraint to a high level of adoption of innovations such as fertilizer use or innovation packages, (e.g., HYV technology) which require fertilizer use.

Perrin and Winkelmann (1976), in a review of studies conducted in association with The International Maize and Wheat Improvement Center (CIMMYT) on the diffusion of new wheat and maize varieties in seven developing countries, also examined whether farm size is associated with the time of adoption and the level of adoption (e.g., percentage of adopters). In about a half of the agro-climatic areas included in the different studies, farm size appeared to have an important effect on adoption, although its impact was reduced in some cases when access to credit and extension are taken into account. This finding, for example, led Colmenares (1975b) in a study of Colombian farmers to conclude that the orientation of credit and extension programs toward larger farmers contributed substantially to a greater percentage of adoption among larger farmers. Vyas (1975) found in India that most of the observed differences between farm sizes in the adoption of HYVs were due to differences in the availability of irrigation water and to a seed distribution policy which initially favored larger farmers. Perrin and Winkelmann (1976) also note that differences by farm size in the adoption of HYVs in Mexico and Turkey (Demir, 1976) were evident even when other factors were taken into account.

Although Perrin and Winkelmann (1976:10) do not summarize the analyses of factors determining adoption decisions regarding fertilizer, they do note that, in contrast to the finding with respect to HYVs,

> ...the scale effect in fertilizer adoption in these studies was more pronounced. ...there appeared to be significant size effects in fertilizer adoption in

> nearly half of the agro-climatic situations considered. Apparently fertilizer use is more heavily influenced by farm size than is variety use, as might be expected due to the greater investment at risk with fertilizer.

In another paper reviewing these same studies, Winkelmann (1976b:12) concludes that:

> Fertilizers are taken up less quickly and tend to be used in lesser amounts than recommended. Farm size generally influenced fertilizer use with smaller farmers usually applying less than do larger farmers in similar agro-climatic circumstances. These actions could be a consequence of differing access to credit and inputs, differing transaction costs, or differing sensitivity to risk between larger and smaller farmers.

The empirical findings reviewed above demonstrate that while there is a correlation between farm size and adoption, the correlation is an indirect one and depends on a number of intervening variables. Thus, for example, various studies report that land ownership is highly correlated with access to institutional credit, input markets, and product markets. Gotsch (1972) and Desai and Naik (1971) report that credit was more readily available to larger than to smaller farmers in India. Hodgdon and Singh (1966) report that farmers in Mudhya Pradesh, India, who owned less than three acres were not able to obtain loans from local cooperatives. Other potentially intervening variables include (1) productivity of the crop (variety) grown, particularly as influenced by agro-climatic and topographical differences; (2) whether the holding is irrigated; (3) tenancy; and (4) the level of uncertainty and risk faced by the farmer. While various studies indicate that fragmentation (extreme subdivision and/or separation of land holdings) is an obstacle to efficient utilization of tubewells (Hodgdon and Singh, 1966; Clay, 1972; Dobbs and Foster, 1972) and chemical inputs such as fertilizer (Hodgdon and Singh, 1966), Schutjer and Van Der Veen (1976) conclude that there is no empirical evidence to indicate the magnitude of fragmentation's influence on adoption.

Unfortunately, as Schutjer and Van Der Veen (1976:21) point out, "most studies do not provide evidence regarding the factors which relate to farm size such as wealth, access to market, etc., which may...account for variation in adoption across farm sizes." While Schutjer and Van Der Veen (1976:21) conclude that "the available literature does not indicate a consistent pattern of size of holding *per se* as a barrier to technology adoption by farmers in the developing nations," the evidence reviewed here indicates that in comparison to smaller farmers larger farmers tend to be earlier in adopting new technology or innovations. The factors which appear to explain this trend may be summarized in four categories: risk, economies of size in fixed transaction costs, economies of size in variable transaction costs, and access to subsidies.

With respect to *risk*, the larger farmer is in a more favorable position than the smaller farmer to invest the additional resources which are usually involved in experimenting with innovations and to undertake experimentation. For example, a trial of fertilizer use on a 1-hectare plot by a farmer owning 100 hectares is a considerably less risky venture than if a 1-hectare trial plot is conducted by a farmer who owns only 10 hectares. One may expect that the smaller farmer's lesser ability to invest in experimentation and to undertake risks associated with such experimentation will initially cause a lag in adoption until enough information becomes available to reduce the uncertainty and risk involved in adopting. Similarly, as compared with larger farmers, smaller farmers may reduce risk by using less than the recommended quantities of inputs.

With respect to *economies of size in fixed transaction costs* the larger farmer is in a more favorable position than the smaller farmer to take advantage of such economies in acquiring and evaluating information about an innovation, in learning about how to use the innovation, and in making purchases. For an increased return of $10 per hectare, the costs of acquiring the necessary information and making the necessary purchases of inputs may be quite worthwhile for the farmer who cultivates 100 hectares but not for a farmer who cultivates only 10 hectares. As information about and experience with an innovation become more common in a farming community, fixed transaction costs, at least for acquisition of information, will fall. Thus, one may expect that economies of size in fixed transaction costs, at least for acquiring information, will occur early in the process of an innovation's diffusion.

With respect to *economies of size in variable transaction costs* the larger farmer, in comparison with the smaller farmer, is in a more favorable position to deal in volume and thereby to obtain a better price in purchasing inputs and selling outputs.

With respect to access to subsidies the larger farmer usually is in a more favorable position than the smaller farmer if he (as the result of discriminatory governmental policies) has readier access to government subsidies in the form of information, credit, or inputs.

Tenancy

Whether the farmer is an owner-operator, fixed rent tenant, or a sharecropper tenant, the concept of tenancy refers to the rights and obligations which a farmer has in occupying and using the land on which he farms. Raup (1963:9) has suggested five ways in which tenancy affects a farm family's pattern of expenditures, saving, and investment, in short, the family's decision making about a farm's operation:

1. the family's time preference for money income;
2. the allocation of expenditures between the farm firm and the farm household;
3. the allocation of expenditures within the farm household as between goods and services for direct consumption and expenditure upon the family residence;
4. the disposition of the total available labor time of the family; and
5. attitudes toward and use made of credit.

Similarly, as Adams and Havens (1966:211) emphasize, the system of land tenure has "significant implications for the kinds of enterprises which will be undertaken on the farm, the types of investments that will be made, the flexibility which is present in the farm operation, and the manner in which production decisions are made and carried out."

In theory, a farmer who is a sharecropper or fixed-rent tenant, is less likely to adopt an innovation if the expected returns extend beyond his tenure or if the value of the farmer's share of the returns is judged by him to be less than profitable in view of the amount of rent he must pay the landlord and the costs he must incur to acquire and apply the innovation. In a similar vein, Nulty (1972:80) suggests that "it is only when a technique requiring cash outlay is introduced that significant differences between owner-operators' and tenants' attitudes to new techniques are observed." Thus, as reported in World Crops (1976:29), farmers in Ecuador's Andes "will tend not to use fertilizers on land they are sharecropping for someone else."

In contrast to such reports and theoretical argument, Newbery (1975:265) observes that "the literature on the 'green revolution' reveals serious difficulties testing the effect of tenure on the adoption of new technology." Even from a theoretical standpoint, the problem of assessing the impact of tenancy on such variables as production and adoption

> ...is confounded by the fact that although leaseholders may have greater investment incentive than share-tenants they have less ability to activate that incentive, for the bulk of public rural credit funds have shown a signal disinterest in leasehold customers even when the banks are offered guarantees by the Government. Share-tenants, on the other hand, can gain effective patronage and cooperation from landlords (Palmer, 1976:125).

Looking at the available empirical evidence, Palmer (1976:125) concluded that the relative adoption performance of leaseholders and share-tenants has been variable. Similarly, Schutjer and Van Der Veen (1976:22) found that the

> ...limited empirical work available regarding the relationship between tenancy and...adoption... indicates no consistent relationship between tenancy...and either adoption or the proportion of cultivated land to which...recommended practices are applied.

Several studies in India, Pakistan, and the Philippines, for example, provide evidence that tenancy is not a significant variable in explaining variation in adoption (Muthiah, 1971; von Blanckenburg, 1972; Castillo, 1975b). Muthiah's (1971) study of Thanjavar District, India, provides some empirical data relevant to this issue (table 9). As Muthiah (1971:56) suggests:

Table 9. Variation in Fertilizer Use and Paddy Yield Between Owners and Tenants, 1968-1969, Thanjavar District, India (Muthiah, 1971:56 as reported in Schutjer and Van Der Veen, 1976:56)

	Kharif Season		Rabi Season	
	Owners	Tenants	Owners	Tenants
Average fertilizer use per acre (Rs)	63	57	83	76
Average paddy yield per acre (kgs)	1,467	1,325	1,433	1,278

> If the...figures [in table 9] are any guide, the tenants of Thanjavar district do not seem to lag much behind owners either in the application of fertilizers, an important and expensive element of the new agricultural strategy, or in productivity of HYV paddy.

On the other hand, other evidence suggests that tenancy and adoption are related, albeit indirectly. Again the link is established through the influence of such intervening variables as access to information, credit, and markets for purchasing inputs and selling outputs. For example, the interrelationship between tenure status and the procedures for obtaining credit from an institutional source (e.g., a bank) illustrates the indirect impact which tenancy may have on adoption. Availability of credit is often interrelated not only with the terms of a loan (e.g., the interest rate) but also with the tenure status of the farmer who is requesting the loan. Whether provided by a bank, a cooperative, or some other institutional source, institutional credit "usually requires land as collateral for loans--collateral to which tenants and landless laborers do not have access" (Hexem, 1971:78). Moreover, even where the tenant farmer could acquire and adopt an innovation through using credit, "the proportion of the net returns going to the landlord and/or the proportion accruing to the marketing middleman may tend to discourage such investment" (Hexem, 1971:78).

It is important to emphasize that a change from the status of a sharecropper tenant to that of a fixed-rent tenant would not necessarily ease the impact of tenancy as a constraint to adoption. For example, Huke and Duncan (n.d.:30) found in the Philippines that

> ...the process of adopting new rice varieties is not encouraged by the transformation from share tenancy to leasehold. In fact the transformation may act to discourage adoption...due to the fact that leasehold operators are seldom able to acquire loans for fertilizer...and other agricultural inputs from the Rural Banks and are almost never extended credit by their landlords who, because of fixed rental, no longer have anything to gain from improved yields.

These farmers on leaseholds are contrasted by Huke and Duncan (n.d.:30) to those farmers in land reform areas who have chosen to continue a share tenancy arrangement: "In such situations capital expenses for agricultural inputs are shared equally and credit is extended with little or no interest by the landlord. His profits come from improved yields."

Additional evidence relating to the extent to which tenancy operates as a constraint on adoption is considered further below in the section on capital availability.

Labor Availability

Theoretically, farmers may meet the labor requirements of their farm operations through family, exchanged, and/or hired labor; and/or adoption of labor-saving technology such as the use of tractors or selective mechanization. Traditionally, the use of tractors has not been economically feasible for the smaller farmer and, until recently, selective mechanization alternatives had not been available to the smaller farmer. Consequently, the smaller farmer has traditionally been dependent on family, exchanged, and/or hired labor as his only means of meeting the increased labor requirements associated with adopting innovations which increase the quantity of labor required in order to grow a crop. There has been increasing recognition, however, that such innovations will not be or are less likely to be adopted if the additional labor required to adopt it can bring a greater return if allocated to other income-earning opportunities in the off-farm rural and urban labor markets. Evidence regarding the importance of labor availability as a potential constraint to adoption is now appearing in such areas as India (Harriss, 1972), Indonesia (Bowers, 1973), Taiwan (Hicks and Johnson, 1974), Mexico (Villa Issa, 1976), and Africa (Lele, 1976).

Villa Issa (1976), for example, found that farmers in the Plan Puebla region of Mexico face a labor constraint on the adoption of the Plan's recommended technology which increases labor requirements by 30%. Analysis of data from a sample of nonadopters and adopters of the recommended technology found that nonadopters participated in the nonfarm labor market more than the adopters. Nonadopters hired 43% of their total labor input, while adopters hired only 23%. These results indicate that there is an interaction between the labor market and the adoption of new technology.

Studies such as these provide increasing evidence "that the availability of labor on the farm will encourage the adoption of labor-intensive technology while a lack of labor will discourage both adoption and efficient utilization" (Schutjer and Van Der Veen, 1976:25). Apparently little attention, however, has been given to the question of labor availability as a constraint on adoption by tenant farmers as compared with farmers who are owner-operators. Theoretically, unless the tenant is confident that use of an innovation will increase his production enough to repay for the increased labor input, it is not likely that he will adopt the innovation.

Summarizing their review of literature with respect to the relationship between labor availability and adoption, Schutjer and Van Der Veen (1976) note that most of the research relating to labor availability and agricultural technology has focused primarily on a technology's impact on the demand for labor. While additional research will be required on the long-run implications of technology on the supply of labor in small farmer agriculture and the implication of alternative technologies for the demand for various skills at the farm level, Schutjer and Van Der Veen also note that the supply of family labor as a constraint on adoption has been a neglected research question which merits more detailed study in future inquiries.

Education

The relationship between education and technological change has been the subject of much attention not only in specific empirical studies on adoption but also in research on the value or utility of education in agricultural development in general (Nelson and Phelps, 1966; Welch, 1970; Schultz, 1975; Sidhu, 1976). Underlying this attention is the hypothesis "that education enhances one's ability to receive, decode, and understand information, and that information processing and interpretation is important for performing or learning to perform many jobs" (Nelson and Phelps, 1966:69). The ability to productively process information is particularly important in farming which entails "a diversified set of activities for which allocative decisions are made continuously as part of the normal routine" (Welch, 1970:47). Moreover, as Nelson and Phelps (1966:70) note, in a technologically progressive or dynamic economy,

> ...productive management is a function requiring adaptation to change and...the more educated a manager is, the quicker will he be to introduce new techniques of production. To put the hypothesis simply, educated people make good innovators, so that education speeds the process of technological diffusion.

The importance of education is similarly stressed by Schultz (1964, 1975). In economies where agricultural production is based on traditional factors and relatively stationary techniques, farmers have ample time to explore the potential of the factors being used. Consequently, traditional factors are likely to be more efficiently allocated than in modern agricultural economies, and traditional agriculture is more likely to operate at or near an economic equilibrium than is modern agriculture. However, once the introduction of modern inputs (e.g., fertilizer) is under way, the traditionally static and low productivity agriculture of the developing countries becomes increasingly complex and dynamic. In a technically dynamic agriculture, "a factor may [become] obsolete before its productivity can be fully explored" (Welch, 1970:47). Adoption of new technology requires that farmers acquire and evaluate information about modern inputs and learn how to use these inputs efficiently. Farmers having only a low level of schooling may require larger time lags to select, assimilate, and allocate new farming skill and inputs. Herein lies the basis for education's facilitation of adoption:

> If educated persons are more adept at critically evaluating new and reportedly improved input varieties, if they can distinguish more quickly between the systematic and random elements of productivity responses, then in a dynamical context educated persons will be more productive. Furthermore, the *extent* of the productivity differentials between skill levels will be directly related to the rate of flow of new inputs into agriculture (Welch, 1970:47).

As is indicated further below (see table 13 in Chapter IV), approximately 75% of the studies of adoption which have included education as an independent variable found a positive relationship between education and both early awareness and adoption of an innovation. For example, Chaudhri (1968, 1973) found in a study of Indian agriculture that farmers with schooling were "in the vanguard in the use of chemical fertilizer" (Schultz, 1975:841). Kothari and Murty (1969:32) also found a strong correlation between education and use of multinutrient fertilizers in a sample of Indian farmers. Their data revealed that the higher the level of education, the higher the percentage of farmers using multinutrient fertilizer. The percentages were 0% for illiterate farmers, 33% for farmers with a primary school education, 47% for farmers with a high school education, and 67% for farmers with a college education. Similarly, Choudhury and

Maharaja (1966:163) found in the Rajasthan district of India that literacy was more closely associated with adoption of improved practices then either size of holding or income.

Kolshus' (1972:104) study of fertilization in paddy farming in Thailand showed an interesting conclusion about the relationship between education and adoption of fertilizer use. While an objective measure of profitability showed that "fertilizer more than paid for its direct cost, ...the visible advantage of its use was not immediately obvious." Kolshus (1972:105) emphasizes that while the "recommended practice...is objectively profitable in economic terms, ...its relative economic advantage becomes obvious only after careful weighing and evaluation of the pertinent data." Using kilograms of fertilizer applied per rai as the dependent variable, Kolshus found that years of formal education (the average level of education in the sample was 3.2 years) was not significant in a regression analysis. Kolshus (1972:103) concluded "that at the level of educational exposure identified in [his] sample, education does not have an impact on the individual's ability to perceive the profitability of fertilizer use when the increase in yield, such as evidenced in [this] study, is not immediately obvious." This suggests that farmers with lower levels of education may not use fertilizer unless it will produce observably larger increases in yields than would be required to convince better educated farmers to use it.

One aspect of education in which many farmers in the developing countries are deficient is literacy, a skill which is essential in order to understand printed information. Studying factors related to acceptance of innovations in Bang Chan, Thailand, Goldsen and Ralis (1957) found that literate villagers adopted a number of innovations earlier than illiterates. Similarly, Rahim (1961) found that literacy was positively related to adoption of improved practices in Pakistan. And Rogers and Herzog (1966), in a study of peasants in five Colombian communities, found literacy to be correlated with early adoption of recommended practices.

The effect of education and literacy on adoption of new technology, particularly as these variables affect an individual's ability to communicate and understand information, has been the focus of attention in many diffusion studies (Rogers and Shoemaker, 1971). In a study of the influence of education and literacy on exposure to instrumental information among 142 operators of small farms in southern Brazil, Fliegel (1977) found that exposure to information was associated with higher rates of adoption of modern practices.[20] However, except for a necessary association between level of education and reading of farm information in newspapers, neither education nor literacy enhanced the exposure to such information through channels such as listening to farm radio programs, personal contact with agricultural technicians, and membership in farm organizations. Interestingly, two of these three channels are interpersonal ones. Fliegel (1966:26-27) notes that since his data show that contact with agricultural technicians is not influenced by literacy or level of education, and exposure to other nonprinted sources of farm information is only moderately influenced by these variables, "the illiterate or poorly educated farmer may not be as hard to reach with instrumental information as is often supposed." Thus, while education and literacy are often emphasized as essential inputs to the development process, it may be the case that these variables do not directly function as constraints on the flow of information through interpersonal channels.

Caution must be exercised, of course, in drawing specific conclusions about the relationship between any two variables, such as education and adoption. However, in a study of adoption of fertilizer among low altitude corn growers in Colombia, Colmenares (1975a:112) found that:

> Education was positively and significantly related to adoption of fertilizers. Although this variable appears associated to other independent variables, it was retained in the equation because of its effect on fertilizer use. For instance, if formal schooling were to be increased from three years of education, which is the average for farmers in [the low altitude zone], to five years, adoption would increase by about 10 percent. Moreover, the full cycle of both primary and secondary school would push adoption of fertilizers among farmers in [the zone] to 41.6 percent (an increase of more than 56 percent over the estimated average adoption level).

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[20] Fliegel (1966:17) was "concerned only with information directly relevant to agricultural production, referred to...as instrumental information to avoid confusion with the broad topic of general media exposure."

In summary, various studies provide evidence that adoption is positively related to both education and literacy. Education is recognized as enhancing one's ability to receive, understand, and act on information about innovations. However, the measurement of this variable in terms of the number of years of schooling completed by the farmer, apparently tells us little about that phase of education that makes any difference with respect to adoption. Obviously, it is not the number of years in school that is the issue but rather the degree to which the amount of education a farmer has acquired enhances his ability to identify and adopt productivity-increasing technologies and/or the requisite inputs of such technologies.[21]

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[21] Increased adoption of fertilizer use might be facilitated to the extent that farmers actively seek information regarding use of fertilizer. Few studies, however, have focused specifically on identifying the factors that determine to what extent farmers actively seek information. One exception is the study which Diaz-Bordenave (1964) conducted on 221 farmers in northeast Brazil. This study sought to identify the factors determining variation in the farmer's "Intensity of Search for Instrumental Information." This variable was measured by an index of scores obtained by farmers in three areas: frequency of use of 16 communication channels available in the study region; the farmer's motive (consummatory or instrumental) for using a particular channel; and the nature of the information received from the channels--consummatory, political, economic, agrarian, agricultural, or general news. In a correlational analysis, Diaz-Bordenave found that Intensity of Search for Instrumental Information was positively related (p. = .05) to an "Index of Dissatisfaction with the Situation," as measured by the farmer's desire for more land productivity and more personal knowledge and information. He also found that the dependent variable Intensity of Search for Instrumental Information was positively and significantly correlated (r = .54) with "Range of Possible Decision Making," measured by an index of scores on: (1) land owned, rented or worked; (2) largest amount of cash held at one time in life; (3) number of workers supervised; (4) occupation outside agriculture; (5) literacy; and (6) schooling. Thus, it would be reasonable to suppose that farmers who have or believe they have a wide range of possible choices in decision making *and* who are highly dissatisfied with their condition would be more likely to seek information that would help them to improve their situation. The higher the individual's education, other things being equal, the more likely he is to be dissatisified with his present situation *and* to see that he has a wider range of decision making possibilities. These conditions prompt the better educated persons to more actively seek out instrumental information.

Capital Availability (Credit)

Selected agronomic practices such as spacing plants for the maximum yield require little, if any, additional capital for adoption. Schutjer and Van Der Veen (1976:28), however, point out that "agronomic practices are only rarely recommended other than as a component of a package of technology which requires the increased use of purchased inputs." The importance of capital availability as a potential constraint on the adoption of technological packages by the small farmer, particularly the sharecropper, is noted by Byres (1972:10):

> The increase in working capital requirements brought about by the seed-fertilizer-water-pesticide package is great and the new profit possibilities are, therefore, confined to those cultivators with large personal resources and/or access to credit on reasonable terms. Small peasants and sharecroppers (who may be one and the same) are thereby excluded, because of the lack of resources and the lack of acceptable collateral. . . . Despite strong attempts to prove the contrary, the evidence is overwhelming that it is rich peasants who have had almost exclusive access to the 'new technology'.

As Gillette and Uphoff (1973) relate, various cultural and social factors can restrict the level of small farmer participation in formal credit programs. In turn, various studies have reported that the lack of institutional credit was a constraint on and/or resulted in a delay of adoption of HYV technology by farmers with limited resources (Sharma, 1973; Hodgdon and Singh, 1966; Desai and Naik, 1971). Limited supplies of credit correspondingly limit the number of farmers who are able to obtain fertilizer and other inputs. Furthermore, to the extent that tubewell irrigation is essential in order to make the adoption of HYVs profitable and credit for investment in tubewells is not available, such lack of credit will indirectly impede the adoption of fertilizer use.

In spite of such studies, there is still debate over the extent to which limited availability of credit is really a constraint on adoption of improved technology. Donald (1976:34) states that "the preponderance of evidence suggests that a shortage of capital is a constraint on the adoption of new techniques by small farmers...when profitable new techniques are available." While differential access to credit is frequently cited as an important factor in explaining why some farmers adopt a new technology and others do not, Schutjer and Van Der Veen (1976:28) state that: "Conclusive empirical evidence regarding the impact of differential access to capital on technology adoption is not available." Of course, it is reasonable to assume that if farmers really need additional funds to purchase the inputs required for the trial or adoption of fertilizer use, they can obtain these funds from other sources such as loans from relatives, off-farm employment, other agricultural enterprises, or even moneylenders. Similarly, farmers can adopt fertilizer use on only a portion of their land or even at a rate of application that is less than that recommended. One may also hypothesize that failure to adopt may be explained by reasons other than lack of credit (Desai and Naik, 1971; Tinnermeier, 1973; AID, 1973; Schutjer and Van Der Veen, 1976).

Although Schluter's (1971:33) study of adoption in India illustrates a close relationship between the use of cooperative credit and adoption of HYVs, Castillo's (1975b) study of adoption by Philippine farmers of various components of HYV technology for rice suggested that credit is neither a necessary nor a sufficient condition for adoption of inputs for rice production. From a study of lowland rice farmers in Laguna province, Castillo (1975b:358) concluded that:

> About 20 percent of the 471 farmers did not borrow money but used improved varieties, fertilizers, insecticides and herbicides. On the other hand, more than three-fourths of those who did not adopt these inputs had borrowed money. In other words, credit helps facilitate adoption but does not determine it.

Regarding the intensity of HYV adoption, Castillo (1975b:358) notes:

> ...a definite positive relationship between cash expenses per hectare and the use of new varieties and other inputs. ...although farmers are spending more when they use inputs they are not necessarily using credit to do so. On the other hand, those who are borrowing money are not necessarily using it to purchase all the inputs.

The evidence presented on the relationship between capital (credit) availability and adoption leaves one at somewhat of an impasse regarding the extent to which capital availability really operates as a constraint to adoption. However, a consideration of this matter in light of various previously reviewed constraints (e.g., farm size, tenancy, and labor availability) suggests that the relationship may be more indirect than direct and depends on various intervening variables. For example, data reported by Griffin (1972) and Whyte (1975a) suggest that supervised credit programs may require that credit supplied to the farmer be used to purchase inputs and in conjunction with certain recommended practices which are not productive in the eyes of the farmer. Consequently, such farmers will be reluctant to acquire additional debt and will not use the available credit. Tecle's (1975) study of the distribution of loans under Ethiopia's Chilalo Agricultural Development Unit also illustrates the interaction between tenancy and credit availability. Tecle (1975:19) argues that most loans were made to large landowners and cultivators such that the sharecropper tenant was expected to use the credit to adopt technology and to pay as much as [illegible]-half of his gross income for rent without getting any compensation for the improvements he might make.

Another intervening variable is the farmer's perception of the extent to which he will be able to get the credit needed to purchase a technology's requisite inputs. This variable's importance is reflected in two studies of adoption of new coffee varieties by Colombian farmers (Havens and Flinn, 1975; and Aiken, et al., 1974). Table 10 reports the statistically significant correlations between adoption and each of the following variables: total credit used, percentage of credit asked for and received, and perception of credit availability. These data indicate that farmers "who thought that credit was not available to them and those who did not use credit...were less likely to adopt..." (Aiken, et al., 1974:17). This relationship is further reflected in table 11 which also reports data on the farmer's subjective evaluation of the availability of credit from three institutional lending agencies. The mean score for perception of credit availability for the two categories of credit users is considerably higher than for the two categories of credit nonusers. As the reader will also note, the lowest mean perception of credit availability score occurs in the category of those who did not ask for credit.

A review of farmer comments is also informative (Aiken, et al., 1974:19): "It is almost impossible to get credit unless you have pull." "It is impossible to get credit unless you have a

Table 10. Interrelationship of Percent of Credit Asked for and Received, Total Credit Used, Perception of Credit Availability, and Adoption of New Coffee Varieties in a Sample of Brazilian Farmers (Adapted from Havens and Flinn, 1975:479)

Variables	Variables[a] 1	2	3	4
1. Percent of credit asked for and received	1.000	.459	.437	.339
2. Total credit used		1.000	.333	.413
3. Perception of credit availability			1.000	.607
4. Adoption				1.000

a. All r_{ij} statistically significant at .05 level.

Table 11. Use of Credit with Adoption of Caturra and/or Borbon and Perception of Credit in a Sample of Brazilian Farmers (Aikens, *et al*., 1974)

Credit Category	Number of Cases	Number of Adopters	Mean Score for Perception of Credit Availability
A. Used credit			
1. Received all credit requested	22	18	1.55
2. Received some, but not all credit requested	5	5	1.40
B. Nonusers of credit			
1. Asked for credit, but was refused	17	0	.65
2. Did not ask for credit	12	4	.58
All respondents	56	27	1.05

lot of land. . . . The last time I asked for credit, my application was tied up in red tape for two years and finally the bank said it wasn't approved." "It isn't easy to get credit because every time I ask, they tell me that I don't have anything for security. So I don't ask anymore." "I can't get credit because the National Agrarian Bank says it doesn't have money to loan, but it does loan money to those who have money." These comments suggest that farmers may believe that credit is possible or available only for the farmers who own land or already have access to other sources of capital.

When potentially intervening variables such as farm size are taken into account, one sees that capital (credit) availability is more likely to be a constraint on adoption of fertilizer use by the smaller farmer who encounters the greatest difficulty in obtaining credit because the potential institutional sources of credit view the smaller farmer as likely to default on loans or as not being able to offer enough collateral. And being a tenant or sharecropper farmer may even make it more difficult to obtain credit for production. Consequently, the smaller farmer, while perhaps having more than an adequate supply of family labor, may not be able to obtain the credit he needs in order to purchase fertilizer and take advantage of his available labor supply. Under these circumstances, capital (credit) availability is likely to be a constraint to the adoption of fertilizer use.

Water Availability (Irrigation)

Timeliness and adequacy of supply of water is crucial to efficient fertilizer use, both to increase average yields and reduce yield variability. Schluter (1974:25) points out that use of fertilizer on unirrigated crops increases the uncertainty of net returns in three ways:

1. If fertilizer is applied and rain does not follow, the crop may be "burnt," thereby resulting in lower yields.
2. If fertilizer is applied and the rains following are substantially greater than expected, the effect of the fertilizer is neutralized by the volume of water, so that the expected increase in yields does not materialize.
3. If fertilizer has been used and the crop fails owing to disease or some other factor, then the net returns will be lower than if fertilizer had not been used.

Thus, when the rainfall is inadequate, the farmer is likely to find that the additional yield obtained by fertilizing a crop does not pay for the additional fertiizer and labor costs involved, and this results in loss not only of the value of the fertilizer but also of a large part of the value of the crop (cmpr. Cone, 1975).

On the other hand, the availability of irrigation would be expected to facilitate not only the adoption of fertilizer use, but also the use of fertilizer-responsive HYV seed and higher rates of application of fertilizer. As Huke and Duncan (n.d.:16) observe, the conversion from traditional to HYV rice involves considerably more costly methods of cultivation in order to achieve the potential yield improvements. Where the farmer is dependent on rainfall alone for an adequate water supply, such additional investments entail considerably greater risks, while on irrigated land a higher rate of return on investment is relatively certain.

In light of these considerations, farmers having access to irrigation would be expected to adopt HYVs or fertilizer-responsive varieties sooner and on a larger percentage of their available arable land than would farmers with no irrigation (cmpr. Nicolas, 1974). Supporting this prediction Huke and Duncan (n.d.: 29) report that in Gapan, Nueva Ecija, the Philippines, the most important factor explaining the variation in the percentage of adoption of a high-yielding variety of rice was the percentage of land irrigated. Irrigation was found to be positively correlated in 1967 (.765), 1968 (.734), and 1969 (.909) with the percentage of farmers adopting the innovation in each of these years. The rate of diffusion was initially slowest where the largest concentration of nonirrigated farm land was located. Of 652 farmers in Gapan having nonirrigated land, 628 were located in Santa Cruz, Kapalangan, and Mahipon--the three barrios having the lowest percentages of adoption in 1968, two years after the high-yielding varieties had first been introduced in Gapan.

The impact of irrigation on adoption is also reflected in Schluter's (1971) study of differential rates of adoption of new seed varieties in India. Schluter found that the differences in adoption levels among farm-size groups were less in the districts studied in Andhra Pradesh than in those studied in West Bengal. The small differences in Andhra Pradesh, Schluter (1971:13) argues, are "probably due to the superior availability of irrigation in Andhra Pradesh. Irrigation reduces yield variability of the new varieties so that a greater proportion of small farmers are willing to adopt." And, in general, Schluter (1971:28) found that adopters of the HYVs had a greater proportion of their land irrigated than nonadopters. Further data from a survey in Surat district in South Gujarat (India) suggested that:

> The uncertainty associated with fertilizer use under unirrigated conditions may be inferred from the relatively slow spread of fertilizer use from irrigated to unirrigated crops on partially irrigated farms. On average, farmers adopted on unirrigated crops initially more than six years after they had adopted on irrigated crops (Schluter, 1974:25).[22]

Prices, Markets, and Infrastructure

The farmer in a developing country is confronted with an environment which includes potential economic constraints in the form of prices, markets, and infrastructure. An unfavorable combination of these factors can seriously impede the transition from subsistence farming to market-oriented or commercial agriculture that is associated with using fertilizer and other purchased inputs (cmpr. Harrison and Shwedel, 1974; Scott, 1974; and London, 1975). Thus, the ability of farmers to raise marketable crops profitably or to adopt innovations such as fertilizer use which require purchasing inputs will depend on the existing price levels, the marketing conditions, and the level of infrastructural development (cmpr. Abbot, 1979).

The extent to which these factors will be influential will, in part, depend on the profit to the farmer of continuing to use a practice already in use rather than adopting a recommended alternative to that practice. On the basis of their literature review, however, Schutjer and Van Der Veen (1976:34-35) conclude that "the extent to which variation in profitability influences the rate of diffusion and intensity of adoption of an innovation has not been adequately researched." They further emphasize that "it is not possible from the literature to document the extent or impact of differential market access on rates of adoption."

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22. The reader interested in further information on socioeconomic aspects of irrigation should review Coward (1976), IRRI (1976), Doherty and Jodha (1977), Coward and Ahmed (1979), Freeman and Lowdermilk (1979a, 1979b), Layton and Lowdermilk (1979), and Lowdermilk and Layton (1979).

Evidence drawn from various sources, however, illustrates the potential impact which infrastructure, markets, and prices can have on the diffusion of an innovation.

Where distances between farm and market are great and transportation is at best only poorly developed, profitable opportunities are likely to be few or nonexistent. This is illustrated in Garst's (n.d.:7) study of the spatial diffusion of new crop varieties in the Kiisi district of western Kenya, "where many of the farmsteads are located as much as a 30 minute walk from the nearest motorable road." Garst's data revealed statistically significant negative correlations between the percentage of semi-subsistence farmers who adopted specific crop innovations and the distance in kilometers between the farm and the nearest point at which the crop is sold. The correlation coefficients were -.69 for coffee sold at the coffee factory, -.66 for pyrethrum sold at a cooperative, -.41 for tea sold at a collection station, and -.55 for passion fruit sold at a collection point.

Inadequate development of a country's infrastructure or markets will make it more difficult for farmers to obtain the inputs they need for adopting yield-increasing innovations such as fertilizer use.[23] In many African countries, fertilizers are simply not available on the market, a factor which obviously explains the nonadoption of fertilizer use by many African farmers. For example, when asked to name the factors responsible for their nonuse and underuse of recommended farm technology (i.e., chemical fertilizers, etc.), 56% of a sample of farmers in eastern Nigeria cited "lack of supply" of the requisite inputs (Awa, 1980). Even where fertilizers are "available," distance, transportation and other infrastructure-related factors will influence the cost of fertilizer as well as the market and price for farm products (Dalrymple, 1975). For example, in a study of ten villages in the district of Maharashtra, India, Savale (1966:205) found that almost 25% of the farmers had not adopted fertilizer use and had cited difficulties of supply as the major reason for not adopting. Commenting on the impact which inadequacies of input supply have on adoption, Savale (1966:208) states:

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[23] Bangladesh is an example of a developing country with infrastructure- and market-related problems in the fertilizer sector. Relevant data are reported in Ahsan (1976), Badruddoza (1976), Quasem (1978), ESCAP/FAO/Bangladesh (1977), USAID Mission to Bangladesh (1978), and Chuang, et al. (1978). Examples of published work on the development of the fertilizer sector in other developing countries are listed in TVA (1970) and various publications of IFDC (1978a, 1978b). A general discussion of fertilizer marketing in developing countries is presented in Mittendorf (1974), FAO (1978), ESCAP (1979), and Lee (1979).

> The problem of supplies is of great importance in inducing farmers to accept new technology. The majority of them did not know the source from which to get the required supplies and the procedures to be followed in this respect. Nonavailability and inadequacy of supply and untimely nature of supplies did affect adoption to a considerable extent.

Various studies similarly point to the physical nonavailability of high quality seeds as a major obstacle to the spread of HYV technology. For example, Sidhu (1974) reports that in India's Punjab good quality seeds were often not available. Most developing countries, argues Dalrymple (1974), have yet to develop a highly advanced seed industry. Thus, the lack of an adequate supply of high quality seed appears to be one of the major hurdles which must be overcome to achieve a rapid and sustained adoption of HYVs.[24] To the extent that adoption of HYVs creates additional incentive for adopting fertilizer use, a lag in the rate of diffusion of HYVs implies a delay in the rate of diffusion of fertilizer use. This is well illustrated by Shetty's (1966) study of the diffusion of fertilizer use in India (see figure 1) and Gerhart's (1975) study of the diffusion of hybrid maize in Kenya (table 12).

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[24] The reader interested in some of the issues related to the development of seed production and distribution systems in the developing countries, with particular emphasis on the administrative aspects of these issues, is referred to Douglas (1980).

Table 12. Percentages of Small and Large Farmers Adopting Improved Maize HYVs and Fertilizer Use by Region and Farm-Size Class in a Sample of Kenyan Farmers (Adapted from Gerhart, 1975:24)

	Region 1	Region 2	Region 3
HYVs:			
Small	95.7	83.7	14.9
Large	95.8	95.1	17.4
Fertilizer:			
Small	47.8	71.4	2.1
Large	75.0	92.5	6.4

CHAPTER IV

SOCIOLOGICAL APPROACHES TO DIFFUSION RESEARCH

Studies of the diffusion of innovations in agricultural production technology have frequently observed that such innovations are generally not simultaneously adopted by all potential adopters but rather are first adopted by farmers having certain characteristics (e.g., such as having larger-sized farms) and subsequently, at successive points in time, by other farmers (e.g., those operating smaller holdings). The initial use of an innovation by those first trying or adopting it has a potentially significant influence on the pattern of diffusion of that innovation in that such trial and adoption serves to "test the waters" or "pave the way" for subsequent adoption by those who, for various reasons, are initially hesitant or unable to try the innovation. For example, in reviewing a number of studies of changes in rice farming in selected areas of Asia, Castillo (1975a:348) concludes that "while the early-adopter-large farmer used partial adoption as a means of reducing risk, the smaller farmers had a 'wait-and-see' attitude. With demonstrated results from larger farms, the small farmers were then willing to go all the way with the new seeds." In this manner, an innovation or the adoption of that innovation may be seen as "trickling down" from larger to smaller farmers or from earlier to later adopters.

Various researchers, however, have begun to question not only the efficiency of this "trickle down" process as a mechanism for diffusing improved technology to smaller farmers in the developing countries but also the efficiency of agricultural extension programs which are based on the assumption that this "trickle down" process provides an effective basis for the design of an agricultural extension program (Rogers, 1974; Beltran, 1974a, 1974b). In view of the assumed efficiency of the "trickle down" process, agricultural extension programs in the developing countries are usually based on what Roling, et al. (1976) call the "progressive farmer strategy." First, the progressive farmer strategy assumes that those responsible for introducing innovations (e.g., extension workers) should use adopter categories to "classify their farmers in terms of progressiveness or innovativeness and make use of this classification to concentrate on" the more progressive or more innovative farmers, i.e., those "farmers who are quick to follow advice, of sufficient means, knowledgeable and homophilous with the extension worker."[25] Second, since the individual extension worker can only have direct contact with a small proportion of the farmers in an area, the "progressive farmer" approach assumes that he should concentrate on those more progressive farmers who are also opinion leaders, i.e., individuals who, if they adopt an innovation, will influence others to do the same. The underlying assumption which supports the validity of these two approaches is that once an innovation has been introduced to and adopted by a few of the more progressive or innovative farmers, information about it will then "trickle down" to other farmers in the area who, upon becoming aware of the innovation, will subsequently adopt it.

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[25] Homophily is the degree to which pairs of individuals who interact are similar in certain attributes, such as beliefs, values, education, social status, and the like" (Rogers and Shoemaker, 1971:14).

The efficacy of the "progressive farmer strategy" as a means of achieving adoption of an innovation by "less progressive" farmers has been brought into question by various researchers (Rogers, 1974; Beltran, 1974a, 1974b, 1976). Most notably, Roling, et al. (1976) have suggested that the "progressive farmer" strategy typically used by extension agencies has tended to increase rather than decrease the development gap between richer and poorer farmers. Supported by various empirical data, Roling, et al. (1974, 1976:160-163) list a number of reasons the process of diffusion has tended to increase the development gap rather than to close it:

1. There is never enough time for all farmers to catch up with those who first adopted; some farmers i.e., the laggards, are finally just adopting an earlier innovation, while others, e.g., innovators, are already reaping benefits from a recently introduced innovation (Ascroft, et al., 1973).

2. Even if an innovation such as a new cash crop diffuses in only 10 years to all farmers in a particular village, those who first plant the crop will receive an income from the crop over an additional number of years; thus, early adopters may move so far out ahead that later adopter may find it impossible to "catch up" (Roling, et al., 1976:161)

3. "Early adopters reap 'windfall profits'.... They start producing at a time when the product is still relatively scarce and when its prices are high. Subsidies or inputs may still be offered as

incentives. Later adopters may find prices low." And later would-be adopters may be legally prohibited from adoption.[26]

4. "Having available funds relatively earlier than others allows acquisition of additional resources when they are still relatively cheaper" (Roling, et al., 1976:161).

5. While ideas may diffuse relatively easily, implementation of ideas requires scarce resources. Typically, ability to obtain such resources is inequitably distributed, thereby providing greater opportunity to those with greater means.[27]

6. It is those possessing collateral who are able to obtain credit. Thus, farmers who are relatively well off are most easily able to obtain costly, and therefore, often profitable innovations. Hale (1974), for example, found in India that the most powerful faction in one village received proportionately more governmental loans (at 9% interest), while lower-caste farmers relied largely on moneylenders whose interest rates ranged from 36 to 72%.

7. Since extension services tend to define the more progressive farmers as their primary clientele or target audience, the continued channeling of new information to this group permits this group continued advantage through early adoption.

8. The recommendations developed by research stations are usually oriented toward the large farmers; as a result, smaller farmers "often do not adopt because the innovations handed down to them may be ill-adapted to their conditions" (Roling, et al., 1976:162). A prime illustration is the agricultural experiment station which focused on

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[26] This is supported by Rochin's (1973:294-295) study of the pattern of adoption of dwarf wheat in Pakistan between 1966/67 and 1969/70.

[27] Reviewing the evidence in the Green Revolution, Ruttan (1977a:20) concludes that when the scale-neutral technology was "introduced in areas characterized by great inequality in the distribution of resources, ...the pattern of inequity has been reinforced...."

developing recommendations for sole cropping, while 80% of the farmers' fields are under mixed cropping for sound reasons.

9. Information diffusing through a social system is subject to a loss of fidelity. Thus, information received by farmers at second, third, or nth hand will be less specific and less reliable (Sinha and Mehta, 1972; Lowdermilk, 1972; and Roling, et al, 1976:162).

10. With the emergence of inequities, "farmers start to experience feelings of relative success and failure. . . . ...those who succeed learn to adapt their 'gets' to their 'wants,' while those who fail learn to adapt their 'wants' to their 'gets'" (Roling, et al., 1976:163).[28]

In short, information about recommended innovations, the adoption of such innovations, and the benefits of adopting these innovations do not readily "trickle down" to all farmers who are potential adopters. This, in part, is explained by the economic factors previously identified in Chapter III's discussion of potential economic constraints to adoption. However, beyond these economic factors, there are also social factors which influence the length of time a potential adopter will wait before adopting an innovation. The body of sociological research in this area is extensive and reviewed in greater depth by Rogers (1962) and Rogers and Shoemaker (1971).

While interest in the impact of social factors on the rate of diffusion has not been confined to any one discipline, the principal contributions to the empirical testing of hypotheses about such variables have been made by social scientists such as sociologists and communication specialists. Researchers working in this area have placed considerable emphasis on (1) identifying which farmers are earlier and which are later in adopting a particular innovation; and (2) identifying the social characteristics

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[28] These points rather clearly substantiate that extension services in the developing countries are effectively subsidizing larger farmers, as well as input suppliers, consumers, etc. In this sense, the extension service fails significantly in fulfilling its role as a "public good" in the extent to which this structure perpetuates inequities in income flows between urban and rural consumers, the latter, of course, being in large part the small or subsistence farmers.

(socioeconomic characteristics, personality variables, and communication behavior) associated with being an earlier or later adopter. One of the major contributions of research in this area has been a system for classifying farmers who have (or who have not) adopted in terms of adopter categories such as innovators, early adopters, ..., laggards. These classifications are based on the farmer's innovativeness as measured by the degree to which he is earlier in adopting an innovation than other farmers in the area under study (Rogers, 1975:14). This system of classification is illustrated in figure 2. Having classified each farmer in a sample in terms of one of the adopter categories, many studies have then examined which social characteristics are associated with which categories.

Sociological research on diffusion has also produced various classifications of the stages in the adoption process. Among the first to point out that an individual's decision to adopt an innovation is a process composed of stages or steps, was Wilkening (1953:9). He proposed that the adoption of an innovation is "a process composed of learning, deciding, and acting over a period of time. The adoption of a specific practice is not the result of a single decision to act but of a series of actions and thought decisions." As Rogers (1962:80) has noted: "There is not complete agreement as to the number of stages in the adoption process, although there is general consensus on the existence of stages, and that adoption is seldom an 'impulse' decision." For example, in his earlier work, Rogers (1962) used a five stage model of the adoption process: (1) awareness, (2) interest, (3) evaluation, (4) trial, and (5) adoption; and described the type of behavior occurring at each stage as well as the main function that each stage fulfills in the adoption process. Then, in a later work, Rogers and Shoemaker (1971) proposed a model of an innovation-decision process consisting of four stages: (1) knowledge, (2) persuasion, (3) decision, and (4) confirmation. Alternative models of the adoption process have been proposed by other researchers (e.g., Benito-Samonte, 1970). Diffusion studies that measured how far each of the sampled farmers has proceeded through specific adoption stages have also frequently identified the source of the information and the communication channels through which farmers have received information at each stage of the adoption process (cmpr. Rahim, 1961 and Menanteau-Horta, 1970).

The following discussion of "innovativeness analysis" and "innovation attribute analysis" summarizes two of the key research approaches and related empirical findings from diffusion

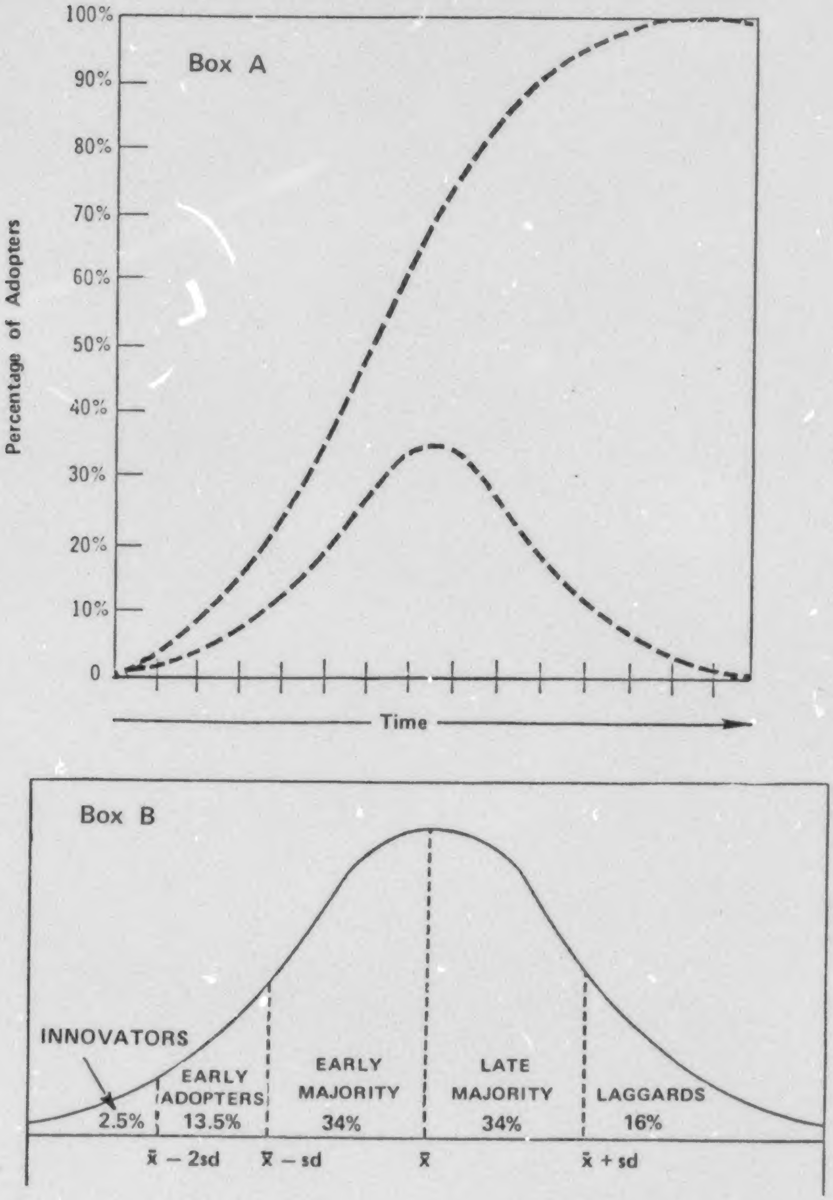

Figure 2. The Bell-Shaped Frequency Curve and the S-Shaped Cumulative Curve for an Adopter Distribution (Box A) and the Adopter Categorization on the Basis of Innovativeness (Box B). The Two Curves in Box A Are for the Same Data: The Diffusion (Adoption) of an Innovation Over Time by the Members of a Social System. While the Bell-Shaped Curve Shows These Data in Terms of the Number of Individuals Adopting Each Year, the S-Shaped Curve Shows These Data on a Cumulative Basis. The Innovativeness Dimension, as Measured by the Time at Which an Individual Adopts an Innovation or Innovations, Is Continuous. However, This Variable May Be Partitioned Into Five Adopter Categories (Box B) by Laying Off Standard Deviations From the Average Time of Adoption. (Adapted From Rogers and Shoemaker, 1971:177, 182.)

research conducted by sociologists and, in some instances, communication specialists.

INNOVATIVENESS ANALYSIS

Various diffusion researchers in the fields of sociology and communication have used the statistical procedure of multiple correlation analysis to test hypotheses concerning the sources or factors which might account for or explain differences observed among farmers in their degree of innovativeness. One advantage of using multiple correlation analysis in studying innovativeness is that this procedure provides an indication of "the degree to which each independent variable is related to innovativeness, while controlling the effects of all other independent variables" (Rogers and Shoemaker, 1971:192). Rogers (1976a:295) has estimated that innovativeness is the dependent variable in approximately 60% of all diffusion studies. Some studies employing innovativeness analysis have explained up to about 80% of the variance in innovativeness. But Rogers and Shoemaker (1971:192-193) note that "most attempts are much less successful."[29]

Review of Innovativeness Analysis

As an approach to diffusion research, innovativeness analysis basically consists of the following steps:

1. Specification of a particular geographic region in which one or more innovations have already been introduced and adopted by a substantial number of farmers.
2. Identification, typically through a sample survey, of (a) which farmers in the specified region have adopted which innovations and the point in time at which they adopted each innovation and (b) which farmers have not adopted.

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[29] Variation in results may be explained in part by variation in the procedures used to measure "innovativeness" (cmpr. Havens, 1962; Rogers, et al., 1962; Jones, 1966; Presser, 1969; Rogers, 1969a, 1969b; and von Fleckenstein, 1974) and "adoption" (cmpr. Rogers, 1958a, 1958b; Rogers and Rogers, 1961; Mason, 1962; Pareek and Chattopadhyay, 1966; Beal and Sibley, 1967; Sengupta, 1967; Dasgupta, 1968; von Blanckenburg, 1972; and Sharma, 1973). It is not surprising in view of the different ways of measuring adoption that Dalrymple (1975a:2) noted that: "More complete measures of fertilizer adoption are clearly needed." See also Mann (1978).

3. Collection of data on any of a number of independent (explanatory) variables (e.g., socioeconomic characteristics of the farmer and his farm, communication behavior, and personality variables).
4. Computation of a score for each farmer's innovativeness (e.g., the number of years which the farmer has been using the innovation).
5. Testing of various hypotheses relating specific combinations of independent variables to the dependent variable innovativeness.

The reader will note that the types of independent variables used in innovativeness analysis are the variables which Brown and Lentnek (1973) refer to as "site-related" variables (see Chapter II). In identifying the variables which are most highly correlated with a farmer's innovativeness score, innovativeness analysis indicates the characteristics of those farmers who are more likely to be earlier or later in adopting an innovation.[30]

The use of innovativeness analysis in diffusion studies has resulted in a large set of empirically based generalizations on individual level correlates of innovativeness (Rogers and Shoemaker, 1971). Table 13 summarizes from these generalizations various characteristics which have been found to be related to early awareness-knowledge and early adoption of an innovation.

In general, those characteristics which have been found to be most closely associated with early awareness-knowledge of an innovation are also the very same characteristics which have most frequently been found to be related to early adoption of an innovation. Those farmers earliest in becoming aware of and subsequently adopting agricultural innovations are, in general, the farmers who:

1. Have larger-sized farms, higher social status, and more years of education (items 1, 2, and 3 in table 13);[31]
2. Have greater exposure to outside sources of information by virtue of (a) being more cosmopolite (item 4) and more likely to seek information about innovations (item 5), and

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[30] Fliegel and Kivlin (1962a, 1962b) and Fliegel, et al. (1968) report research on the correlation between attributes or characteristics of innovations as perceived by farmers and the rate of diffusion of these innovations. A discussion of this area of research is presented later in Chapter IV.

[31] Measures of social status include self-perceived identification with a social class, occupational prestige, income, level of living, and possession of economic resources.

Table 13. A Summary of Studies Providing Empirical Support for a Relationship Between Each of the Listed Characteristics and Early Awareness-Knowledge and Early Adoption of an Innovation (Adapted from Rogers and Shoemaker, 1971)

Item	Characteristic[a]	# Support	% Support	# Not Support
1	Have larger sized units	152[b]	67	75
2	Have higher social status	275	68	127
		(18)	(64)	(10)
3	Have more years of education	203	74	72
		(17)	(71)	(7)
4	Are more cosmopolite	132	76	42
		(5)	(100)	(-)
5	Seek information about innovations	12	86	2
6	Have greater exposure to mass media	80	69	36
		(18)	(62)	(11)
7	Have more change agent contact	135	87	21
		(23)	(81)	(3)
8	Have greater exposure to interpersonal communication channels	46	77	14
		(16)	(89)	(2)
9	Have greater knowledge of innovations	61	76	19
10	Have more social participation	109	73	40
		(11)	(85)	(2)
11	Have a higher degree of opinion leadership	42	76	13

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a. For any one characteristic to be included in table 13, the author required that the number of studies providing empirical support of the hypothesized relationship between a particular characteristic and early adoption of an innovation be at least 60% of the total number of studies which included that particular characteristic.

b. Numbers in parentheses correspond to relationship between listed characteristic and early awareness-knowledge of an innovation, while numbers not in parentheses correspond to relationship between listed characteristic and early adoption of an innovation.

(b) having more frequent contact with the mass media, change agents (extension workers) and personal communications with others (items 6, 7, and 8);[32]

3. Have greater knowledge of the innovations (item 9); and

4. Have more social participation and a greater degree of opinion leadership (items 10 and 11).[33]

In short, farmers having these characteristics are more likely to become aware of and adopt innovations earlier than farmers not possessing these characteristics or possessing them in a lesser degree. With the exception of the size of the farm, social status, and possibly education, all of these characteristics are communication-related variables which are influential in determining the likelihood that a farmer will receive information about an innovation. On the other hand, farm size, social status, and education will, through their influence on the various communication-related variables, be indirectly influential in determining the likelihood that the farmer will receive information about an innovation. For example, the larger farmer is more readily able to afford a trip to the city or to the experiment station. Additionally, farm size and social status will be influential in determining the farmer's ability to finance and bear the risk of adopting an innovation once he has become aware of it.

An illustration of the empirical application of innovativeness analysis in explaining variation in the time of adoption of fertilizer use is provided by Shetty's (1969a) study of fertilizer use by farmers in India (cmpr. Choudhary and Prasad, 1978). As the reader may observe in table 14, the set of characteristics which distinguish between early and later adopters of fertilizer use consist largely of the same characteristics listed in table 13. Table 14 also illustrates the influence on time of adoption of several variables such as farm size, fragmentation, and irrigation earlier discussed in Chapter III as potential economic constraints to adoption. The set of variables in table 14 were also found to explain almost 68% of the variation in an index of fertilizer use. And, as seen in table 15, size of the farm owned and the assets available were also found to distinguish between heavy and moderate users of fertilizer.

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[32] Cosmopoliteness is measured by, for example, number of trips he has taken to the city.

[33] Social participation is measured by organization membership as well as informal group participation.

Table 14. Average Characteristics of Early and Late Adopters of Fertilizer Use in Two Villages of India (Shetty, 1969a:57)

Characteristics	Units	Early Adopters N = 16	Late Adopters N = 77	Estimated Value of "c"
Subsidiary occupation	Scores	3.94	2.98	4.00[a]
Age	Years	48	50	0.28
Size of cultivated holding	Acres	9.35	3.04	5.62[a]
Irrigated area	Percent	48.11	36.74	1.96[b]
Fragmentation	Number	2.38	3.03	2.36[a]
Socioeconomic status	Scores	12.38	7.24	4.13[a]
Extension contacts	Scores	7.06	3.86	3.73[a]
Educational level	Years	10.16	1.75	7.28[a]

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a. Statistically significant at .01 level.
b. Statistically significant at .05 level.

Table 15. Average Characteristics of Heavy and Moderate Users of Fertilizer in Two Villages of India (Shetty, 1969a:58)

Characteristics	Heavy Users N = 14	Moderate Users N = 19	Estimated Value of "t"
Size of owned land holding	4.54	1.59	4.04[a]
Index of assets	11,385	3,290	2.56[b]

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a. Statistically significant at .01 level.
b. Statistically significant at .05 level.

In contrast to such variables as farm size which were earlier identified (in Chapter III) as potential economic constraints to adoption, the variables identified here as important are primarily social variables which describe the farmer's behavior with respect to the communication of information about innovations. As shown in table 13, these social variables primarily describe the farmer's use of interpersonal channels of communication to exchange information about innovations. The importance of interpersonal communication channels is particularly great in the developing countries where, in contrast to the more developed countries, farmers are less able to rely on the mass media for information about innovations in agricultural production technology (Rogers and Shoemaker, 1971:256-258). This inability stems from the lack of media in some instances, the frequent lack of relevant information in existing media and, in the case of printed messages, low literacy levels of those who read them. For example, in Brazil, Fett (1970) found in a content analysis of Rio Grande do Sul newspapers that agricultural news was only 7% of the total news and that only 8.8% of the agricultural news had situational relevance, that is, had information that farmers could use in their farming operations. Fett (1971:365) also reported "that although readership of agricultural articles was higher than that of nonagricultural articles...most farmers did not understand technical and semitechnical terms widely used in the mass media."

Generally lacking mass media sources that provide relevant information, farmers in the developing countries have had to rely principally on contact with others to become aware of and acquire information about an innovation (compr. Byrnes, 1969; Rogers and Shoemaker, 1971; Rao and Moulik, 1966). For example, in a study of adoption of various farming practices by Philippine farmers, Feliciano (1964) found that approximately 7 out of every 10 farmers cited conversations with extension workers or neighbors as influential in their decisions. Typical comments were: "My neighbor convinced me to try it," "My neighbor said it was a good practice." "The FHD [extension] worker explained it so well I decided to follow his advice." "That FHD man was convincing." Similarly, Liao and Barker (1969:19) found in their study of the diffusion of new HYVs of rice in the Philippines "that information on new varieties appears to spread primarily by word-of-mouth." Specifically, "the earliest and relatively early adopters obtained the information from extension workers. By contrast, the later adopters got the information from their neighbors or local farmers."

Another point which can be noted with reference to table 13, particularly in regard to the variable of social participation (item 9), is that various data indicate that farmer organizations such as credit groups, may be influential not only in communicating information to farmers but also in facilitating access to credit, fertilizer, and other inputs. For example, such effects were observed in the case of the Puebla Project in Mexico (compr. Felstehausen, 1973; Diaz-Cisneros, 1974; and Byrnes, 1975). Similarly, years of membership in a Farmers' Club was found to be positively related to the level of fertilizer application in a study of Thai farmers; this suggests

> ...that membership in a voluntary and progressive organization such as the Farmers' Club results in a higher application rate of fertilizer when its rate of return is modest, overcoming by social sanctions and improved communication of the non-dramatic profits, the lack of perceived economic profitability of fertilizer (Kolshus, 1972:154).

Statistically significant positive correlations between membership in organized groups and both amount and type of fertilizer used are also reported in a study of innovativeness among subsistence farmers in Guatemala (Nesman, et al., 1974).

Although not listed in table 13, several studies employing innovativeness analysis have found a number of psychological variables to be correlated with early adoption of an innovation. For example, Hurt, et al. (1977:54) used a 20-item Likert-type self-report scale to measure "innovativeness as a normally distributed, underlying personality construct, which may be interpreted as a willingness to change..." This use of the term "innovativeness" by Hurt, et al. (1977) should not be confused with the same term's use in reference to the extent to which an individual is earlier or later than other individuals in adopting an innovation. However, as summarized in Rogers and Shoemaker (1971), earlier (as compared with later) adopters were found to be less fatalistic (empirically supported by 82% of the studies employing this variable); to have a more favorable attitude toward change (75%), education (81%), and science (74%); to have higher aspirations (for education, occupation, and so on) (74%); and to have a more favorable attitude toward risk (73%) and credit (borrowing money) (76%). Also, earlier adopters have been found to have a commercial (rather than a subsistence) orientation

(71%). While such attitudes may favorably influence farmers holding them to decide to adopt an innovation, it may also be the case that such attitudes would logically be expected to be held by farmers who are in a more favorable situation with respect to resources (e.g., the larger farmer).[34] This same argument also applies in the case of studies which report empirical evidence to support a positive correlation between individual modernization and psychological traits such as need achievement (cmpr. Singh and Ray, 1980).

Finally, it should be noted that several studies by sociologists have focused on clarifying the impact of system effects as compared to individual effects in the process of an innovation's diffusion in a social system and the innovation's adoption by farmers (cmpr. March and Coleman, 1956; van den Ban, 1960; and Saxena, 1971). Of particular interest here are those studies which attempted to measure the effect which a community's norm on innovativeness has on the adoption of new technology. Such a norm, if operative, would provide the individual farmer with a guideline for determining whether he should or should not try new technologies or innovations when these become available. In these studies, the researcher has attempted to measure a community's norm on innovativeness by means of averaging the innovativeness scores of the individuals included in the community in question. As previously discussed, an innovativeness score provides a measure of the extent to which an individual is earlier or later than other individuals in the same community in adopting new technologies or innovations.

The procedure of averaging the innovativeness scores of individuals in a particular community as a means of measuring that community's norm on innovativeness has been questioned by Flinn (1970) who has used several alternative methods to deal with the measurement problem of separating social structural (e.g., a community's norm on innovativeness) from individual effects.

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[34] Seligson and Salazar (1979) report a study in which higher levels of interpersonal trust were found among peasants than among urbanites in Costa Rica. In this regard various researchers have investigated the influence of "interpersonal trust among peasants" as a potentially important factor influencing the process of agricultural modernization (e.g., adoption of recommended practices). While Seligson and Salazar do not report any data on the adoption behavior of the peasants in their sample, the study's findings do serve to raise the question of how important "interpersonal trust among peasants" really is in adoption and diffusion processes.

These methods are summarized in table 16. As an alternative approach to measuring a community's norm on innovativeness, it may also be possible to follow up on Flinn's (1970:989-990) observation that:

> More appropriate questions for assessing a community value system would deal with the farmers' perception of whether most farmers in the community feel that innovativeness is important or not. Perhaps a Likert-type scale (strongly agree to strongly disagree) could measure the perceived value system. An example of a statement might be: 'In this community most farmers consider the old, established ways of farming best.' This same approach could be employed to measure the normative structure concerning innovativeness. Thus values and norms of the collective could be assessed by respondents' perceptions and not by analytical constructed measures of norms and values.

The approach of developing a Likert-type scale, as proposed by Flinn, would also reduce the possible difficulty with autocorrelation which might be present in using the methods outlined in table 16.

Critique of Innovativeness Analysis

Typically, studies employing innovativeness analysis have relied heavily on conducting a correlational analysis of data gathered in a one-shot survey of farmers. In such studies, as Rogers (1976:295-296) notes:

> It is implied that the independent variables "lead to" innovativeness, although it is...unstated or uncertain whether this really means that an independent variable causes innovativeness.

However, for a variable X to be the cause of variable Y, X must precede Y in time, they must be related or covary, and X must have a "forcing quality" on Y. While studies employing innovativeness analysis have demonstrated that certain independent variables covary with innovativeness, such studies, relying on correlational analysis of one-shot survey data, have not been able to determine

Table 16. Three Methods to Isolate Structural Effects[a] (Adapted from Flinn, 1970)

Method and Previous User	Data Required	Data Obtained by	Analysis Made by
Analytical Structural Effect-Multivariate Table (Blau, 1960)	A measure of whether or not individual lives in community where farmers have a positive attitude toward individuals who are first in adopting new technology	Asking question: "What is your opinion of farmers around here who are first to use new ideas or practices in farming?"	(a) Dividing communities into two categories: where X% or more of the community residents have a favorable attitude toward innovators and Y% < X% have a favorable attitude toward innovators; and (b) within each category, dividing respondents into those who have favorable attitudes toward innovators and those who do not
Analytical Structural Effect-Partial Correlation (Tannenbaum & Bachman, 1964)	A measure of extent to which individual lives in community where farmers have a positive attitude toward individuals who are first in adopting new technology	Asking same question as above	(a) Assigning as each individual's score the actual % of sampled respondents from his community who have positive attitudes toward innovators; and (b) taking correlation between Y and %, while holding individual's attitude toward innovator and other individual level variables constant
Perceived Structural Effect-Partial Correlation (Campbell & Alexander, 1965)	A measure of extent to which farmer sees his community as one in which farmers are early in adopting new ideas and practices in farming	Asking question: "In your opinion, compared to other communities around here, is your community generally earlier or later in having farmers who adopt new ideas and practices in farming?	(a) Assigning to each individual the actual % of respondents who perceive their community as one in which farmers are early in adopting new practices in farming; and (b) taking correlation between Y and %. while holding individual's attitude toward innovators and other individual level variables constant

the time order of the variables in question. In this respect studies employing innovativeness analysis face a problem

> ...that might be called "yesterday's innovativeness": In most diffusion surveys, innovativeness is measured "today" with recall data about past adoption behavior, while the independent variables are measured in the present tense. It is obviously impossible for individual's attitudes, formed and measured now, to cause adoption of an innovation three years previously (this would amount to X following Y in time order, thus making it impossible for X to cause Y) (Rogers, 1976a:296).

Thus, as Rogers and Shoemaker (1971:192) observe, most diffusion studies in actuality achieve "'postdiction' rather than 'prediction' in that they [do] not validate their predictions on a future sample of similar respondents."

A second major weakness of innovativeness analysis has been its tendency to focus on certain characteristics of individual farmers while failing to give adequate attention to availability of information, perceived credibility of information sources, and social structure as potential social constraints to adoption.

Information Availability

The information needed by farmers to reduce the uncertainty associated with decision making regarding whether to adopt a recommended innovation does not always reach the farmers who could most benefit by access to and use of such information. Indeed, the assumption often appears to be made that the relevant information about an innovation will eventually "trickle down" from innovators to laggards, that is, from the early adopters to the later adopters. To the contrary, evidence from various studies suggests that this "trickle down" process is not as effective as assumed in getting information about improvements in agricultural production technology to farmers. Moreover, the evidence suggests that the lack of (1) "awareness-knowledge" about the existence of improved technology as well as (2) "how-knowledge" essential to utilization of such technology can be significant constraints to adoption.

Awareness-Knowledge--The influence of the lack of awareness-knowledge of the existence of new technologies on the adoption of these technologies is reflected in several studies. Rogers and Niehoff (1967) estimated that 60-70% of the farmers in one diffusion study in eastern Nigeria had not adopted various agricultural innovations simply because they did not know about them. This is particularly significant because that lack of awareness-knowledge about and consequent nonadoption of agricultural technologies (e.g., HYVs) which are complementary to fertilizer use decreases the farmer's demand for fertilizer to less than it would likely be if the farmer had adopted such technologies. Thus, for example, if the percentage of farmers adopting agricultural innovations in the production of vegetables (5%), rice (6%), or improved varieties of palm (20%), cassava (2%), cocoa (4%), and maize (16%) had been higher, then the percentage of farmers using fertilizer probably would have been much greater than the percentage (22%) of farmers using fertilizer at the time the study was conducted. However, 60-70% of the farmers did not know about these innovations; consequently, their lack of awareness-knowledge about technological alternatives would appear to be a potentially important factor in explaining why fertilizer had not been used by more farmers.

Peters (1973) carried out a study to determine the factors which would explain why a large number of the farmers in the state of Puebla, Mexico, did not participate in the Puebla Project. Operationally defining participation by the appearance of a farmer's name on an institutional group credit list, Peters found that, after almost 4 years of the Puebla Project's existence, 90% of the farmers in the region were not participating in the project in 1971. Interestingly, an evaluation survey made in the Puebla region during that same year revealed that 53% of the farmers interviewed were unaware of the Puebla Project, in other words, unaware that there existed an opportunity to participate. Similarly, 65% were unaware that an extension worker had given any talk about the project, 66% were unaware that any agricultural demonstration had been organized, and 66% were unaware that the project film "Would You Like to Increase Your Corn Harvest?" had been shown.

Williams (1968), investigating whether Nigerian farmers had any knowledge of demonstrations of improved farm practices (for fertilizer use, cotton, and rice), found that 5% or less of the farmers had seen a farm practice demonstration even though "the demonstration or experiments were mostly carried out on farmers' farms. One can only infer that the extension agents just applied these fertilizers on farmers' plots without bothering to acquaint them with the details" (Williams, 1968:29). Reasons given by farmers for not seeing fertilizer demonstrations included "did not know about them" (28%) and "was never invited to see them" (63%).

Farmers, of course, will vary on whether they are aware of the existence of a particular innovation. Puteh and Hashim (n.d.:47), for example, in a study of adoption of agricultural chemicals by paddy farmers in the MUDA Project, West Malaysia, found that: "When farmers were asked why they were not adopting the 'package' recommendation of fertilizers, many respondents indicated that they were not aware of the 'package' deal." On the other hand, Obibuaka and Hursh (1974) found that 79% of a sample of farmers in eastern Nigeria were aware of the existence of extension programs on fertilizer use. Awareness of an innovation's existence, however, does not ensure that the farmer will try or adopt that innovation. Only 25% of the farmers were applying fertilizer during the year in which the Obibuaka and Hursh study was conducted. While almost 80% of all farmers were aware of fertilizer, 75% were either nonusers (61%) or ex-users (14%). Thus, as Obibuaka and Hursh (1974:119) state, "knowledge...far exceeded adoption."

How Knowledge--The term "how-knowledge" refers not only to information about the proper use of an innovation but also to information which the farmer needs to have in order to make decisions about the economical operation of his farm holding. Thus, "how-knowledge" includes information not only about the agronomic factors that influence the technical operation of a farm but also about the various factors which influence the economic performance of the holding (cmpr. Muggen, 1969). The importance of how-knowledge (or as it might be more conventionally termed, technical knowledge) as it affects a farmer's production and income has been demonstrated by Bhati (1973) in his study of Malaysian rice farmers. However, as in the study reported by Obibuaka and Hursh, the level of awareness-knowledge of an innovation can far exceed not only adoption but also how-knowledge concerning proper use of the technology in question. Thus, lack of how-knowledge about a technology may preclude not only efficient use but also adoption of the technology.

While there is ample evidence that farmers respond to economic incentives (cmpr. Schultz, 1964; Welch, 1968), there is also evidence that many farmers in the developing world may not have enough "how-knowledge" to understand what the extension worker is trying to communicate to them. That farmers vary in the degree to which they comprehend economics terminology, for example, is demonstrated by Felstehausen (1965, 1968) who measured the degree to which farmers and high school students in a Netherlands farming community comprehended economics terms and concepts. The comprehension was higher for economics concepts which represent events or relationships that are a part of personal experience than for theoretical concepts. Farmers tended to score higher than students on those concepts which could be observed within the marketplace or in the course of the individual's making farm management decisions. Felstehausen (1965:92-93) concludes:

> Agricultural information people should not expect to reach all farmers in a community like Bennekom with the same degree of effectiveness by presenting all material at one level of difficulty or via one medium. . . . Information generally understood may still not reach some farmers if transmitted only through mass media and groups. This implies, for example, that programs such as agricultural extension which are committed to helping all farmers, should use several levels of approach and not just one. In some cases, separate programs may be needed for farmers who are non-readers and non-joiners.

What do we know about farmers' comprehension of economics and technical concepts in developing countries where the differences between subsistence and commercial farmers are even greater than among the commercial farmers of Bennekom? The importance of how-knowledge in relation to the innovation of fertilizer use is reflected in Elbow's (1976:230) review of the response of Guatemalan subsistence farmers to the increases in fertilizer prices during early 1974:

> ...Guatemalan farmers do not know enough about fertilization practices to obtain optimum yields. The quantities of fertilizer applied are usually quite small...and the selection of a time for application often seems to be based on a combination of hearsay, folklore, and whim. Perhaps more serious is the lack of adequate information about soil properties to guide the choice of fertilizer composition. Soil test data are rarely available, and selection of fertilizer type is usually made on the recommendation of a salesman or a neighbor, or as a result of trial-and-error experimentation. Few if any small farmers, therefore, derive the full benefits of fertilizer application.

Rogers and Shoemaker (1971:247) report an example of the problems which can occur if adopters do not have the "how-knowledge" needed to evaluate the innovation which has been adopted:

> Peasants in India commonly refer to superphosphate fertilizer as "sugar" because of its white crystalline form. A popular saying is: "The more sugar added, the sweeter the yield." However, these Indian villagers had no idea of the biochemistry of fertilizer effects on crop yields nor of the importance of soil testing as a basis for wise fertilizer application. Therefore, they applied overdoses of superphosphates and damaged their crops. This illustration emphasizes the importance of educating clients as to the basic scientific reasons why an innovation has its desired effects. Otherwise, the clients are likely to misuse the innovation....

Another illustration is provided by the case of the agricultural change agent in India who persuaded farmers to adopt nitrogen fertilizer but did not teach them anything about how fertilizers stimulate plant growth. "When superphosphate fertilizer became available the next year, the change agent had to repeat his campaign approach, because his clients still had not gained an ability to evaluate innovations by themselves" (Rogers and Shoemaker, 1971:247).

Kolshus' (1972:118) study of paddy farming in Thailand also shows the importance of adequate knowledge about fertilizer use in ensuring high rates of fertilization. Obtaining a score for each farmer on a fertilizer knowledge quiz, Kolshus found that the farmer's knowledge about fertilizer was significantly and positively related to the rate of fertilizer application. Although the line of causality is not demonstrated, Kolshus (1972:164) concludes "that the more an individual knows about fertilizer (directly applicable knowledge), the better able he is to perceive the profitability of its use."

Of course, the longer the farmer has had to experiment with and use fertilizer on his own farm, the more he will know about how to use this input profitably. For example, Kothari and Murty (1969:35), in a study of Indian farmers, found that the farmer's years of experience in using fertilizer was significantly related to the quantity of fertilizer used by him. Of 17 farmers who had used multinutrient fertilizer, 10 had more than a decade of experience in using this fertilizer and applied on the average about 85 kg per acre. The remaining seven farmers had only about

5 years of experience with multinutrient fertilizer and applied on the average about 68 kg per acre. Similarly, the first year a new fertilizer became available, those farmers who had had more experience using fertilizer applied the new fertilizer at a higher rate than that used by farmers who had fewer years of experience in using fertilizer.

But long experience in the use of fertilizer does not guarantee that farmers will use recommended fertilizer application rates or that farmers will use balanced dosages of fertilizer. Mahbub-e-Ilah (1974:13), for example, found in Comilla, one of the more progressive areas of Bangladesh agriculture, that "the farmers of Comilla...have used 49.5% of the recommended doses of fertilizer for improved variety of paddy and have used only 15% of the recommended dose for local variety." When the farmers were asked questions about the function of each fertilizer, only 7 out of 50 farmers sampled could correctly give at least one function of each fertilizer; 37 could give only one function for less than three fertilizers; and 6 did not have any idea about the functions of any fertilizers.

These examples highlight the importance of how-knowledge in relation to the level or intensity of adoption of fertilizer use, i.e., the quantity of fertilizer used by the farmer. The relationship between how-knowledge and adoption per se, however, may also be seen if we examine additional data. For example, in Nigeria, Obibuaka and Hursh (1974) found that 75% of the farmers did not use fertilizer. Many farmers although aware of an innovation's existence did not possess relevant factual information about the innovation. Regarding a question about whether fertilizer was a plant food or a medicine, 21% of the farmers believed fertilizer to be a medicine, while another 24% did not know whether fertilizer was a plant food or a medicine. Similar inadequacy in knowledge about such inputs as Aldrin dust and Ns-1 maize was also found (Obibuaka and Hursh, 1974:118-119). The farmer's lack of knowledge about these suggests that the farmer's failure to use these complementary inputs may provide an additional explanation of why fertilizer was not being used by more farmers.

Krishna, et al. (1975) studied the level of knowledge which trained and untrained Indian farmers had about hybrid maize cultivation. They found a statistically significant correlation between a farmer's knowledge about fertilizers and the degree to which the farmer has participated in a short course on hybrid maize cultivation. However, while 36% of the trained farmers were highly knowledgable about the use of fertilizers in hybrid maize production, as many as 44% of them had low levels of knowledge. Moreover, 88% of the untrained farmers were found to have little knowledge about fertilizer. Since fertilizers and other inputs, such as plant protection measures, form important components of the recommended technology for cultivating hybrid maize, "the lack of knowledge about these major inputs is likely to be one of the major reasons for nonadoption of the same" (Krishna, et al., 1975:341). Gowda (1977) similarly reports in a study on the fertilizer adoption behavior of farmers in Karnataka, India, that lack of precise knowledge about balanced fertilization was one of the factors explaining nonadoption of this practice. And, in a study of agricultural extension in the adoption of innovations by cocoa growers in Ghana, Opare (1977) found that the growers who have a correct understanding of the principles underlying recommended cocoa practices are more likely to adopt them than farmers not having such understanding.

In a study of the responses of farmers in Longos, Philippines, to a field demonstration on the effects of varying rates of fertilizer application, Villegas (1966) gathered pre- and post-demonstration data on the farmer's knowledge, understanding, and attitude toward use of fertilizer. Villegas further classified his respondents into various subgroups of either "high yield farmers" or "low yield farmers" and either "users" or "nonusers" of fertilizer. "The different yield potentials of these groups of farmers were used to determine to what extent farmers accustomed to different mean yields respond differently to the same demonstration treatment, with response being ascertained with respect to knowledge, understanding and attitude related to...the use of fertilizers" (Villegas, 1966:5). While knowledge of fertilizer did not increase appreciably among those who were already users, both knowledge and understanding did increase significantly among nonusers (Villegas, 1966:73). In terms of the potential for adoption, "more low yield farmers were willing to change the level, rate and time of applying fertilizer than high yield farmers, and conversely more high yield farmers desired no change in these respects than low yield farmers" (Villegas, 1966:74). These results illustrate how an increase in the farmer's how-knowledge about fertilizer use can change his attitude toward and the likelihood of adopting this practice. Villegas proposed that future research should attempt to measure whether increases in levels of knowledge and understanding as well as changes in a positive direction in attitudes toward fertilizer use are indeed followed by adoption of this innovation and/or an increased rate of application (cmpr. Leuthold, 1960; Rogers and Havens, 1961). In a related vein, Menanteau-Horta (1970) found, in a sample of Chilean farmers, a statistically significant and positive relationship between level of exposure to technical media and favorable attitudes toward recommended practices.

Perceived Credibility of Information Sources

While the farmer's acquisition of awareness and how-knowledge will be considerably influenced by the social and economic variables previously discussed, there is at least one other social variable that appears to be extremely influential in determinng the rate at which an innovation diffuses, namely, the farmer's perception of the credibility of the information sources to which he has access. Rogers and Shoemaker (1971:244) define credibility as "the degree to which a communication source or channel is perceived as trustworthy and competent by the receiver."

Studies on persuasion have provided substantial evidence that a person's reactions to information provided by a source are significantly affected by cues as to the communicator's intentions, expertness, and trustworthiness. Hovland, et al. (1965:35) reported in the early 1950's that while it was not possible from the results of their studies "to disentangle the effects of the two main components of credibility--trustworthiness and expertness--...it appears that both are important variables." A preliminary analysis in the mid-1960's of more than 900 documents then in the Diffusion Documents Center indicated that few of these reflected any explicit or implicit use of the variables of expertness or trustworthiness in field studies of innovation adoption and diffusion (Byrnes, 1966:242).[35] Since the mid-1960's few studies have focused in any depth on the credibility variable (cmpr. Cuyno, 1967; Byrnes and Byrnes, 1971; Rogers and Shoemaker, 1971:244-246; Ariffin, 1976; Canedo, 1976; Ambasta, 1978; and Swamy, 1979).

It nevertheless seems reasonable that the farmer's perception of the credibility of a source of information about innovations in agricultural production technology will be positively correlated with adoption. More specifically, the more favorable a farmer's perception of an information source's competency on farming matters, the more likely is the farmer to be confident in the source's recommendations and to adopt the recommended innovation. As Stevens (1977:250) argues, an essential

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[35] The Diffusion Documents Center is now located at the Institute for Communication Research, Stanford University, Palo Alto, California.

> ...requirement for effective extension work is sufficient knowledge and ability on the part of the extension agent to competently demonstrate and instruct farmers in the use of...new technology. Many extension agents in low-income nations know less about...crops and farming practices than the farmers they are supposed to educate in the new technology. Until the extension agent can confidently demonstrate all aspects of the new technology, his influence on increasing technology flow to farmers will remain weak.

Various data provide illustrative support for these hypotheses.

A farmer's perception of the farming competency of an information source such as an extension worker may have considerable influence on the farmer's decision to follow or not follow a source's recommendations. This is reflected in various field studies. For example, Beal and Sibley (1967) attempted to measure the impact of information source competency on adoption in a study of the Quiche Indians in Guatemala. Although neither objective measures of an information source's competency nor subjective measures of the farmer's perception of the source's competency were obtained, farmers using chemical fertilizers on corn were asked from what source they had learned about this practice. Responses were categorized into three judged competency levels (Beal and Sibley, 1967:78):

> Competence level 1: These are informal, face-to-face interactions, at a fairly intimate level and probably do not involve thorough knowledge of farm practices; these are personal sources. Examples are family, friends, neighbors.
>
> Competence level 2: These are mass media or commercial businesses and agencies which are not in themselves the scientific information sources but they have close contact with them. These are impersonal sources and have only part-time involvement in research and education regarding farm practices.
>
> Competence level 3: These are scientific information sources either doing the actual research or performing interpretive services to farmers. These sources are

> most often in direct personal contact with the farmers who name them. They deal with individual problems and give instruction to groups through demonstrations, field days, or group meetings.

Beal and Sibley (1967:104) report a positive correlation (r = .5095, p = .0005) between the information source competence level score and a farm practice adoption score.

It is important to bear in mind, however, that the assumption that the extension worker or his research counterpart are necessarily the most competent information sources may be erroneous. Indeed, as reported in an FAO study, "lack of knowledge by farmers _and_ _extension_ _officers_ is one of the main factors limiting fertilizer use in the developing countries" (emphasis added; International Agricultural Centre, 1978:2). The lack of such knowledge or expertise on the part of extension workers may in part explain why extension services are not more effective in providing the kind of information which farmers need to improve the economic performance of farm holdings.[36]

Of the farmers who responded in a study (Umali and Feliciano, 1963-64) carried out in the Land Reform Area, Bulacan, Philippines, 60% recalled that the extension worker had made one to three visits to the barrio and 38.5% that he had made more than three visits. A measure of the influence of extension workers in the barrios is found in the opinions of the farmers as to who among the barrio people should take the leadership in an agricultural improvement project. Only 21% said the extension worker, while 36% named the barrio captain and 22% a barrio council member. Those choosing the extension worker said they would do so for this knowledge of farming methods and his personal traits of helpfulness, kindness, and leadership.

Other studies (Castillo, _et_ _al_., 1963; Castillo, 1964) similarly reflect the importance of an extension worker having, among other qualities, a knowledge of farming methods. Skepticism among Philippine farmers was substantially reduced when extension workers demonstrated a readiness to carry on above and beyond the call of duty. Actions favorably perceived by farmers included getting into the paddy to plant rice, remaining in the barrio to work on Sundays and holidays, and arriving for evening classes despite heavy rains and bad roads.

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[36] An analysis of 36 small farmer development projects in eight developing countries, for example, found "that, overall, traditional extension services--delivered by area-based agricultural experts dealing with individual farmers--were the least effective mechanisms for transmitting useful and used agricultural knowledge" (Morss, 1976:8). Ambasta (1978:8) reports from a study in India that the field demonstration was the most credible communication medium for "popularising balanced application of fertilisers."

The proper promotion of some innovations may require that the extension worker engage in certain farming practices that may appear strange to the farmers in his audience. In such instances, as illustrated by the experience of an extension worker who was placed in charge of carrying out a field trial of various innovative practices in a Philippine barrio (Byrnes, 1966), the farmer's perception of the extension worker's farming competency is a crucial factor in determining how quickly recommended innovations will diffuse. Further data suggest that the farmer's perception of the competency of the change agent in other fields such as economics, may significantly influence the farmer's perception of the change agent's credibility (Contado, 1968; Byrnes and Byrnes, 1971). For example, in a study of 150 Malay peasant farmers, Ariffin (1975) identified the economic and subject-matter competence of extension workers as an important factor in any effective program for change in peasant rice farming.

Beyond the credibility of the extension worker as an information source, Ambasta (1978:8) reports from a study in India that the demonstration was the most credible communication medium for "popularising balanced application of fertilisers."

Social Structure

Interpersonal communication among farmers in a community can facilitate or impede the flow of information about innovations in agricultural production technology. One hypothesis which has been advanced is that certain sociological variables (e.g., cosmopoliteness) which describe characteristics of individual farmers are influential in determining the nature of interpersonal communication among farmers (cmpr. van den Ban, 1977) and the speed with which information about an innovation (e.g., its profitability) is communicated from one farmer to another. The potential importance of such variables arises in part from several advantages which interpersonal communications have over the mass media as a source of and channel for information about innovations. As compared with the mass media, interpersonal communication has the following advantages:

> ...(1) it is more casual and therefore less inclined to attract only persons already sympathetic to the view expressed, (2) it is more flexible in countering resistance, (3) it provides immediate personal rewards for compliance, and punishment for noncompliance, ...and (4) the receiver can ask questions to the sender in order to decrease his uncertainty on the effects of the new behavior (van den Ban, 1977:199; cmpr. Lazarsfeld, et al., (1948).

And, as Sherif and others found in laboratory experiments (Hovland, et al., 1965), in situations where uncertainty is involved interpersonal communication can influence an individual's perception of the effects of an innovation.

Studies employing innovativeness analysis, however, have typically not observed, on an ongoing basis, interpersonal communication among farmers. While many studies have provided information about the social and economic characteristics of early and later adopters, as well as of opinion leaders, these studies usually provide little, if any, information about a farming community's social structure as a potential constraint to the flow of information. An important exception to this generalization is provided by Hale's (1974, 1976) case study of a number of villages in India in which several characteristics of village social structure were found to affect not only the pattern of interpersonal communication among farmers but also farmer utilization of other information sources and the levels of knowledge about and adoption of the recommended innovations.

Hale found in the villages in which she conducted her study that farmers had low awareness-knowledge about a number of development projects which had been operating in those villages from 10 to 15 years. Many farmers knew of some HYVs of seeds, but only 11% knew the names of the most recent varieties for the two principal staple crops and rice. Eighty-nine percent named one or another brand of chemical fertilizer, but only 40% were aware of both surface (topdressing) and basal modes of fertilizer application. Awareness-knowledge of pesticides was even more limited--45% were not able to name any pesticide, and another 12% were able to name only one pesticide. Only 30% were aware of multiple cropping techniques. Overall, Hale (1974:19) estimated that 60% of the farmers in the villages studied had not adopted the full package of recommended practices and "are in fact ignorant of their availability or importance."

In attempting to explain these findings, Hale discovered that the communication of information in an Indian village takes place in a social and political system of caste and factionalism, i.e., there is a leading faction of villagers comprised of a village headman and his followers, a group of rivals, and a neutral group which includes farmers from high to low castes. In this system the more powerful villagers, usually the headman, exercise considerable control over the three principal communication channels within the village that farmers might use to obtain first-hand information about alternative technologies--face-to-face communication with officials (e.g., extension workers); attendance at meetings of village clubs where development projects were discussed by development officials; and mass media such as development publications, film shows, and radio programs. That such control operates to constrain the flow of information to farmers is evidenced by the following findings reported by Hale (1974):

Face-to-Face Contact--The headman usually met and entertained visiting officials, and the meetings and discussions which such officials held with villagers were confined primarily to the headman's immediate friends and associates, thereby generally ignoring lower strata and hostile factions.

Officials were highly selective in terms of seeking out and spending most of their time with individual farmers in the higher caste and wealthy strata, i.e., those who comprised the bulk of the headman's supporters.

> It was widely attested in the poor, low caste, residential areas, that Block officials never entered their streets but were only to be seen taking tea on the headman's front porch. Such company proved more congenial to their status and more advantageous for impressive statistics on size of investment in new programs (Hale, 1974:10).

Persons from lower strata were reluctant to seek out officials at their office; this reluctance was supported by the knowledge that "the few who did so were often ignored by petty officials or left sitting in a passage most of the day" (Hale, 1974:10).

Attendance at Meetings of Village Clubs--Such clubs as were operating were usually directed by the village headman who, when requested by development officials to arrange meetings, normally invited his own supporters, rarely including lower strata and hostile faction members. "For some clubs over 80% of villagers were not directly invited, and the majority appeared unaware of their existence" (Hale, 1974:11).

Mass Media--Generally, access to printed media was restricted by illiteracy, limited purchasing power, and patterns of communication that were sharply defined along stratum and faction lines.

1. Printed Matter (e.g., Extension Pamphlets)--A first restriction on access to relevant literature was a high rate of illiteracy: 60% of all household heads interviewed had no education and another 16% had not completed primary school. A second restriction was that most of this literature was distributed only from the Rural Community Development Program Office at the level of the Block (an operational unit for rural community development projects) or through the radio listening club; thus, the restriction on the farmer's access to face-to-face communication and meetings of village clubs also restricted his access to relevant literature. Of the farmers interviewed, only 12% had read two or more publications on agriculture; only 7%, one; and a fourth of these found that the publication was too hard to understand.

2. Radio Programs--Listening to radio programs was restricted to those owning or having access to a radio: 85% of the farmers did not own radios, and of the 15% owning radios, 56% were members of leading village factions or other high castes; of course, those "owning a radio have direct control over who is invited to listen to it, and this is invariably restricted to immediate friends and neighbours" (Hale, 1974:12).

While each village had a radio supplied by the Block, the village headman usually regarded this radio as his private property and thus directly controlled the access of others to the set; when meetings were organized to listen to the radio, invitations were selectively extended to his own clique of friends and only a few of the lower strata or rival faction members were ever invited to his home to listen to the radio.

3. Films--While free and presented in a public place, films were shown too infrequently to be of much significance as sources of information. Even when films are shown, it is "those having frequent contacts with officials who receive prior warning . . . and invariably the same privileged stratum members command

the best viewing positions, with others at the back" (Hale, 1974:13). Also, since the films were shown under open-air conditions, with usually poor sound reproduction, there was frequently some question whether anything was understood from a film.

These data suggest that access to first-hand information on a regular basis was "restricted to a narrow faction of the villagers, with a majority having limited, or often no direct access" (Hale, 1974 13-14). This pattern of information flow was further evidenced in Hale's data on the distribution of awareness-knowledge across faction and caste groupings, with supporters of the headman's faction having the highest percentage of informed persons on every development project. As Hale (1974:16-17) emphasizes:

> The rival faction groups, although comprising largely high caste and big farmers, have a generally lower level of information on these projects. The middle and low castes who comprise the majority of all the villages, have the minimum proportion of informed persons. This discrepancy increases further if the combined range of projects known is considered.

These conclusions were further substantiated by several instances where information about specific projects was repressed or blocked by village leaders who disapproved or who had an interest in restricting circulation of information to others. For example, many farmers, particularly among the low caste and poorer sectors, were ignorant of the availability of credit through the Rural Community Development Project.

Summarizing her study, Hale (1976:Abstract) states:

> ...within the highly stratified village communities, first hand access to new information, and further diffusion at second hand, will be concentrated among members of the same faction and social stratum as initially privileged informants. Vertical diffusion of information across strata will be minimal, and its content strongly biased by the particular interests of initial informants. ...evaluation of the merits of any new proposals will be strongly influenced by the character of relations between informants and recipients. As information flows vertically between

> strata, its persuasive impact will decline, as a function of relatively poorer quality information, the extent of tensions and conflicting interests between strata, and perceived economic disparities. Lastly, ...access to any input facilities will be concentrated among members of the same faction and social stratum as those persons responsible for their distribution. Access by members of other strata will decline with increasing social distance, and their preferences are progressively less likely to be considered in the investment of resources for community projects.

In summary, information about an innovation's existence or on how to use the innovation does not always or necessarily "trickle down" to all potential adopters. This observation or conclusion questions the validity in concept and efficiency in practice not only of the "trickle down" process but also the "progressive farmer" strategy. First, while an extension worker must work with a relatively small number of farmers, it does not follow that selecting as the primary target group those farmers who traditionally have had the greatest contact with extension, namely, the larger and more progressive farmer, is the strategy that will have the highest probability of accelerating the rate of diffusion among small farmers. Second, the extension worker who only directs his efforts toward those progressive farmers who are also opinion leaders tends to forget that "the opinion leader is very much like the person he advises" (Robertson 1971:184), that interpersonal communications occur mostly among those who are homophilous (Rogers and Shoemaker, 1971:212), and that each level of farmers, from larger to smaller, may have its own opinion leaders instead of a few persons who play this role for the whole community.

In view of these considerations, one recognizes that innovations or information about innovations may not so readily diffuse from larger to smaller farmers if the innovation is only, or primarily, introduced to and initially adopted by larger farmers. Nevertheless, as Roling, et al. (1976:159) note, the effect of the "progressive farmer" approach has been to "provide intensive assistance to a small number of innovative, wealthy, large, educated, and information-seeking farmers, and to expect that the effect of such assistance will reach other farmers indirectly by autonomous diffusion processes." But, as is becoming increasingly apparent, the process of diffusion in developing countries has not operated "autonomously" to the benefit of one and all. Indeed, as Roling (1975:14) has concluded, "there are so many flaws in diffusion processes that our efforts result in increasing inequity...."

Finally, information about innovations and the communication of such information to farmers is undoubtedly important. However, the inefficacy and/or inefficiency of the "trickle down" process (as a means of rapidly communicating information about innovations to farmers), coupled with the constraining influence which structural factors (e.g., credit availability) have on the farmer's access to the facilities (e.g., inputs) required in order to enable him to adopt, suggest that the relevance of information and its communication is highly situational. As Grunig (1970:597) concluded in a study of communication and the economic decision-making processes of Colombian peasants:

> Communication behavior and its concomitant social-psychological variables are a function of the situation in which an individual performs. Communication can have little effect in modernizing peasants unless situational changes first make modernization possible. Effective communication must then be related to the problematic aspects of the situation if its content is to be situationally relevant. Situationally relevant content is a necessary condition if communication is to play a complementary role in the development process.

Similarly, in a study of economic knowledge, participation, and farmer decision making in the Netherlands and Colombia, Felstehausen (1968:281) concludes:

> ...that the value of economic knowledge in rational decision making is meaningful only in societies where the decision maker is free to act on the basis of new information. . . . In less developed countries like Colombia, new information is not the primary shortcoming. Technical programmes among the majority of Colombian farmers depend first on their being able to gain some control over the local institutions and agencies which provide them with informational and other agricultural services.

As a concluding note, it should be emphasized that social structural variables such as caste, factionalism, or as earlier noted, differentiation, can vary from one farming community to the next and that such variation should be taken into account in designing policies and programs to stimulate adoption of recommended technology--rather than assuming that such potential constraints to adoption are not there and that information will "trickle down" to most, if not all, farmers.

INNOVATIVENESS ATTRIBUTE ANALYSIS

The research approach referred to here as "innovation attribute analysis" has been used by various researchers to test the hypothesis that a farmer's perceptions of an innovation's attributes are key variables in determining how quickly a farmer will adopt an innovation. As Kearl (1976:165-166) has emphasized:

> 1. The way the farmer perceives his situation will govern his response to recommendations received from outside, and both his perceptions and his situation may differ considerably from that assumed by development planners.
>
> 2. Individual farm situations differ more widely, as regards land tenure and capital and labor supply, then macrolevel programs and recommendations often recognize.
>
> 3. Appropriate programs usually cannot, therefore, be designed without informed local input, an awareness of local variations, and a systematic effort by change agents to monitor the compatibility of their objectives with the personal and economic objectives of the farm family.

Recognition that the perceptions held by the farmer are influential in determining the rate of diffusion of an innovation is of particular importance from the standpoint of the increasing emphasis being placed on the development of agricultural innovations appropriate to the needs, resource base, and preferences of the smaller farmer, rather than simply assuming that technologies initially adopted by the larger farmer will eventually "trickle down" to and be adopted by the smaller farmer.[37]

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[37] Evenson (n.d.) notes that national governments in the developing countries "simply have not given investment emphasis to research programs. They have persistently overestimated the diffusability of final technology and of building-block knowledge." The increasing emphasis being placed on the development of technology appropriate to the conditions of small farmer agriculture is reflected in a growing number of reports: Schultz (1964), Wharton (1969), CIMMYT (1970), Wellhausen (1970), Adams and Coward (1972), CIAT (1972, 1973, 1974a, 1974b), Schumacher (1973), Tinnermeier and Dowswell (1973), Biggs and Tinnermeier (1974), Harrison and Shwedel (1974), Tinnermeier (1974), Merrill (1974), McRobie and Hodgkinson (1974), Franklin and Scobie (1974), Roling (1974a, 1975), Crawford and Ward (1974), Lund (1975), Streeter (1975), World Bank (1975), Zulberti, _et al_. (1975), de Janvry (1975), Dillon (1975), Pinstrup-Andersen and Byrnes (1975), Pinstrup-Andersen and Diaz (1975), and Pinstrup-Andersen, _et al_. (1976). Selected aspects of this literature are reviewed in Byrnes (1975). See also Miracle (1968), Patrick, _et al_. (1975), Morss, _et al_ (1975), Kluck (1976), Shwedel (1977), Stevens (1977), Wilson (1977), Zuckerman (1977), Hunt (1978, 1979), IMC (1978), O'Sullivan-Ryan (1978), Trew (1978), Bradfield (1979), Deere and de Janvry (1979), Greenwood (1979), Harwood (1979), and Zandstra (1979) for additional discussions relating to small farm agriculture in the developing countries.

Particularly relevant is the work of the Institute of Agricultural Science and Technology (ICTA) in Guatemala, the Centro Agronomico Tropical de Investigacion y Ensenanza (CATIE) in Costa Rica, and the International Potato Center (CIP) in Peru to develop appropriate agricultural production technology for small farm agriculture. The work of ICTA is reviewed in Fumagelli and Waugh (1977), Hildebrand (1976, 1977a, 1977b, 1978), ICTA (1977), and Waugh (1975, 1976). The work of CATIE is reviewed in Navarro (1977a, 1977b), Moreno (1977), Onoro (1977), Andrade (1978), and Moreno and Saunders (1978). The work of CIP is reviewed in Accatino and Horton (1978a, 1978b). See also Ryan (1977), Bartlett (1978), Biggs (1978, 1980), Ryan and Rathore (1978), Doherty (1979), Valdes, _et al_. (1979), Winkelmann and Moscardi (1979), and Norman (1980).

The role which the social scientist can play in agricultural and rural development programs is discussed by Whyte (1975b), Saint and Coward (1977), van Dusseldorp (1977), and Oshima (1977).

Indeed, the increasing emphasis on the development of agricultural technology tailored to the needs, resource base, and preferences of the smaller farmer is indicative of what Whyte (1975a:1) has described as "a veritable revolution in the thinking of those undertaking agricultural development projects" (cmpr. Bunting, 1979:6-7; IDS, 1979).

A concrete illustration of this "revolution" in perspective is seen in the Puebla Project in Mexico. After an initial period of two to three years during which the number of adopters of the Project's recommendations increased rapidly, the Project staff found that the rate of diffusion began to slow down. At this point, Project efforts shifted from trying to persuade farmers to adopt the recommended innovations to doing field studies of the farms of the more successful nonadopters. In contrast to the Project's original recommendations of a single commodity (maize) cropping system and fertilization with commercially purchased inorganic fertilizer, the Project found that the more successful nonadopters used two production systems--a rotation of corn and beans and the interplanting of these two crops.

> In the rotational system, the farmer began with a planting of corn supported by a rather heavy application of chicken manure. The second year, the farmer planted beans without any fertilizer at all. For the third year, the farmer reverted to corn but this time applied a small amount of chemical fertilizer--or else he shifted back to the first year strategy with another generous application of chicken manure.
>
> In the inter-planting system, the farmer planted beans between the rows of corn, either at the same time or several weeks after he had the corn in. With this system, the bean plants used the corn stalks to climb on and, by approximately doubling the intensity of the use of his small plot of land, the farmer was able to increase his income from the land very substantially (Whyte, 1975a:5).

After these discoveries, the Project researchers found that the net income from "the maize-bean association...was approximately double that obtained with either maize or beans alone" (CIMMYT, 1974:24). However, while farmers were achieving good results with their traditional systems, the researchers recognized that better results might be achieved if indigenous (farmer) knowledge and scientific (laboratory and experimental station) knowledge could be integrated rather than relying solely on one or the other of the two knowledge sources. For example, the researchers found that while in the rotational system chicken manure was rich in specific elements needed by the plants, several important plant nutrients were totally lacking. This could be remedied by applying a relatively small amount of appropriately mixed fertilizer. Also, if fertilizer was applied in the right quantity at the right time, the farmer could plant seeds half as far apart as had been customary in Puebla and thereby increase productivity. Summarizing the results of the Project's research to upgrade the productivity of the existing (traditional) cropping system, CIMMYT (1974:29) reports:

> Bean production increased remarkably when ten ton/ha of chicken manure was added to the treatment (of other recommended fertilizers).... The common maize-bean association, fertilized with nitrogen and phosphorus, produced 59% more lysine than did opaque maize alone. The common maize-bean association, fertilized with nitrogen, phosphorus, and chicken manure, produced 2.39 times as much lysine as opaque maize alone.[38]

These results, based on research conducted during 1970-72, were finally translated into recommendations in 1973 and made available to farmers. However, reflecting on the experiences related above, Whyte (1975a:7) suggests:

> ...that if CIMMYT had begun to study the actual farming practices in Puebla with the beginning of the project in 1967, project recommendations for the associated cropping of maize and beans could have been ready three years earlier. In all probability, this would have resulted not only in a gain in time but also in the level of acceptance of CIMMYT recommendations by the farmers, who had naturally tended to discount even the valid recommendations of CIMMYT because some of them had learned from experience that they could do better with their own customary practices.

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[38] Lysine, an amino acid, is present in only very small quantities in ordinary maize.

If this is a valid conclusion, then the most important social lesson of the Puebla Project becomes clear, namely, that the project only began to realize its potential when project officials began to recognize the knowledge that could be gained by studying the agricultural practices of the small farmer and then devising an improved set of recommendations based on the results of scientific research and the most effective agricultural practices used by the small farmers in Puebla (Whyte, 1975a:11).

This social lesson is seen as having significant implications for agricultural research and extension programs in the developing countries. Specifically, argues Whyte (1975a:14-15), the experience gained in the Puebla Project suggests that agricultural research and extension programs need to: (1) relate to agricultural systems in such a way as to foster a two-way flow of information; (2) recognize the importance of the information which may be learned from the experience of small farmers; and (3) give a high priority emphasis to obtaining from these farmers more comprehensive information regarding their agricultural systems and evaluations of recommendations that would involve changing these systems. Thus, the research problem becomes that of developing research designs capable of producing information on the needs, resource base, and preferences of the smaller farmer. This is the sort of information that can be used in guiding basic and applied agricultural research in the direction of developing and testing innovations in agricultural production technology that are appropriate to the realities of small farmer agriculture. The importance of this kind of a methodological approach is emphasized by Pinstrup-Andersen and Diaz (1975:51):

> Priorities in applied agricultural research are frequently established on the basis of very limited information about existing problems and their relative economic importance in the production process. The communication between the farm sector and the research institute is often poor, and the demands at the farm level for problem-solving research frequently are not well known to the research manager. Farmers in most developing countries, with the possible exception of large commercial farmers and members of efficient producer associations, have great difficulty communicating their needs to...research institutes because of institutional and social barriers. As the result, some research may be irrelevant to the actual farm problems and results may not be adopted.

> ...certainly one of the main reasons for...low adoption rate[s] is that new technology does not always meet the most urgent on-farm needs and farmer preferences. A continuous flow of information to the research manager on the potential gains...in various research activities...will help ensure that new technology corresponds with the farmer's needs and preferences. This, in turn, will accelerate adoption and increase research payoff.

The orientation advocated by Pinstrup-Andersen and Diaz is basically one that emphasizes the importance of a two-way flow of information as the key to effectively and efficiently developing higher productivity technology and securing adoption of this technology by the smaller farmer. Various conceptual frameworks of this two-way flow of information process have been proposed (see Chapter VII). Here, however, the discussion will focus only on a review and critique of "innovation attribute analysis" as used in diffusion research to study the effect which farmers' perceptions of an innovation's attributes have on the diffusion of that innovation.

Review of Innovation Attribute Analysis

As a research approach, innovation attribute analysis treats an innovation as a complex entity having various attributes. "Each attribute can theoretically have a positive or negative effect on the rate at which an innovation is adopted" (Fliegel, *et al*., 1968:439). The impetus for developing measures for analyzing the impact of the perceived attributes of an innovation on the rate of diffusion of that innovation is found in the observation "that different innovations cannot be presently compared. There is no systematic basis for deciding in what way or ways one innovation is comparable with another, and thus one cannot effectively capitalize on present knowledge of diffusion processes" (Fliegel, *et al*., 1968:438). Elsewhere Fliegel and Kivlin (1966b:236) note that: "Failure to take into account similarities and differences among innovations makes it problematical at best to generalize from the known determinants of adoption of a given innovation to a second or third innovation."

To deal with this problem, a number of studies have attempted

> ...to construct a set of general categories which describe the salient aspect of...many different new things and ideas. . . . Yet the categories must be specific enough so that they can be shown to have a unique relationship with decisions to accept or reject innovations (Fliegel, et al., 1968:438-439).39

Similarly, Rogers (1962:124) has argued that the extent to which a particular innovation possesses a specific attribute should be measured from the viewpoint of the potential adopter or rejector of that innovation. To minimize variability stemming from personal and situational factors, innovation attribute analysis has typically studied relatively homogeneous samples, i.e., the farmers in a sample have similar situational and personal characteristics. Also, the researcher typically selects a number of innovations which have been recommended to farmers in the sample area over a given period of years.

In the study reviewed here, Fliegel, et al. (1968:439) attempted to measure the perceptions of Punjabi farmers regarding the degree to which an innovation possessed each of 12 different attributes and to determine to what extent innovations differing in their attributes as perceived by farmers also differ in their rate of diffusion. The dependent variable, rate of diffusion, was measured by asking each farmer to specify in which year he started using each of 50 selected innovations and then plotting the cumulative percentages of farmers adopting each practice over the specified period of years (1950-1965). The rate of diffusion was estimated

> ...by (1) determining the average period of most rapid acceptance of all practices [in the sample]; and (2) calculating the percentage of respondents adopting a particular practice per year for the sample average period of most rapid growth as applied to that practice. The procedure is somewhat arbitrary but provides a simple way of assigning an innovation a score for rate of [diffusion] which directly reflects the steepness of slope of [the innovation's] growth curve (Fliegel, et al., 1968:442).

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39. For a more detailed treatment of innovation attribute analysis, see Fliegel (1956); Fliegel and Kivlin (1962a, 1962b, 1966a, 1966b); Fliegel, et al. (1971); Kivlin (1960); and Kivlin and Fliegel (1967).

For the sample of Punjabi farmers, the scores ranged from 1.4 to 12.3%.

To measure the independent variables, the farmer's perceptions of each innovation's attributes, a four-point scale was administered to the farmer who

> ...was asked to assess each innovation and assign it a score ranging from low to high in terms of the four points of the scale. . . . Typically, a sample respondent could go through the rating procedure for the entire list of innovations on three or four attribute scales without losing interest. When the respondent did become tired or lose interest, the interview was terminated and the next respondent was asked to rate the list of innovations on the succeeding three or four attribute scales (Fliegel, _et_ _al_., 1968:442).

An average of 30 individual ratings was obtained for each innovation on each scale and these were then pooled to obtain median attribute scores. Table 17 reports the zero-order and partial correlations between each attribute and rate of diffusion.

In view of the small number of cases (50 innovations), purposive selection of the sample, and measurement problems, one should regard the coefficients as suggesting what might be found if more rigorous statistical criteria were met. Fliegel, _et_ _al_. (1968:443) stress that one should focus on "relative magnitudes and signs of coefficients in interpreting the results, rather than statistical significance in a strict sense." With these cautions in mind, the analysis revealed that the magnitude of financial return was clearly overshadowed by other attributes for the Punjabi sample. This indicates that the approval of others was the more important incentive, a finding interpreted by Fliegel, _et_ _al_. (1966:446) as suggesting "that a relatively high degree of commercialization and of integration into the market economy will be necessary before direct financial incentives become a decisive factor among farmers such as those in the Punjabi sample." Also, the Punjabi farmers were found to be faster in adopting innovations with high clarity of results.

Critique of Innovation Attribute Analysis

Innovation attribute analysis, as used in such studies as Fliegel, _et_ _al_. (1968), raises several methodological problems

Table 17. Zero-Order and Eleventh-Order Partial Correlations Between Attributes of Farm Practices and Rates of Diffusion in a Sample of Punjabi Farmers in India (Adapted from Fliegel and Kivlin, 1966:238-241 and Fliegel, *et al.*, 1968:444)[a]

Attributes	Expected	Zero-Order	Partial
Cost Attributes			
Initial cost: how much does it cost to buy or start using ________	-	.10	-.10
Continuing cost: how much money does it cost to run or to keep using __________	-	.19	.34
Returns			
Rate of cost recovery: how long does it take to get time, labor, or money costs back on __________[b]	+	.16	.21
Payoff: how well does __________ pay off (in money)	+	.16	-.04
Social approval: are people likely to look up to a farmer because he uses __________	+	.56	.46
Efficiency			
Saving of time: how much time does __________ save in getting the immediate job done	+	-.27	-.30
Saving of discomfort: how much does __________ save hard, dirty, or sweaty work	+	-.21	.12
Risk and Uncertainty			
Regularity of reward: does _______ show results every time	+	.21	.02
Divisibility for trial: how easy is it to try out __________ first, on a small scale	+	-.11	-.15
Communicability			
Complexity: how easy is it to understand and use __________	-	-.15	-.06
Clarity of results: how clearly do results of __________ show up	+	.40	.28
Congruence			
Association with major enterprise: how much does __________ have to do with your major enterprise of farm	+	.20	.08

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a. With N = 50 (innovations), r values of 0.23 and 0.27 are required for statistical significance at the .05 level for the zero-order and partial coefficients, respectively. The probabilities are one-tailed.

b. Field ratings were revised to conform to the wording of the attributes.

which are briefly reviewed here. First, this procedure has principally been used as an ex post basis, i.e., for studying the diffusion of an innovation after it has already diffused. Ideally, if knowledge of the farmer's perceptions of an innovation's attributes is to be of practical use, one should be able to predict, on the basis of knowledge of the farmer's present perceptions of an innovation's attributes, the rate at which that innovation will likely diffuse. Most, if not all, studies which have used innovation attribute analysis have involved a time lapse between (1) the farmer's decision to adopt or reject an innovation and (2) the measurement of (a) the outcome of the farmer's decision and (b) the farmer's perceptions of the innovation's attributes. Thus, rather than diffusion being a function of the farmer's perceptions of the innovation's attributes, it may be that the farmer's perceptions are a function of the experience which the farmer has had with an innovation which has already more or less diffused throughout the community in which the farmer lives. The practical implication of this observation is that the relationship between a farmer's perceptions of an innovation's attributes and the decision to adopt or reject that innovation is one which should be measured before or at the time when the farmer makes his decision and not after the fact (cmpr. Jedlicka, 1979a).

Second, the measurement of individual perception of an innovation's attributes have been at best "an estimate of the shared perceptions of a particular segment of the community, the [sample of farmers having] been selected to minimize socioeconomic differences" (Fliegel and Kivlin, 1966b:240). Consequently, innovation attribute analysis has not allowed for the full range of variability in perceptions that may have existed in a community and partially determined the differential rates of diffusion between those farmers included and those farmers not included in the sample. One solution to this problem would be for future studies to focus on a narrower range of innovations and attributes and to include a larger number and diversity of farmers in the sample.

Third, if an innovation is viewed as having several attributes and if these attributes are hypothesized to influence a decision to adopt, a test of such a hypothesis must take into account the attributes as a whole and not just individually. As Fliegel and Kivlin (1966b:240) emphasize:

> This is not to argue that the potential acceptor or rejector of an innovation can precisely weigh and balance a variety of perceived attributes of that

> innovation in arriving at an adoption decision. The point is that if various attributes are perceived, the possibility of interrelationships among them must be taken into account.

Fourth, in conceptualizing and developing measures of a farmer's perceptions of an innovation's attributes, researchers using innovative attribute analysis have not taken advantage of theoretical work in microeconomic theory with respect to the factor bias of inputs to agricultural production (cmpr. Mungia, 1975:3-10). As illustrated by table 18, the inputs which enter into a specific innovation in agricultural production technology may be classified in terms of their factor bias and potential yield effects. The concept of factor bias refers to the relative intensity of use of a particular factor input in producing a standard unit of output of a commodity (e.g., rice). Thus, factor bias is an indicator of the effects of a specific technology on factor shares or contributions to the total output. As Gotsch (1972:328) notes:

> Neoclassical economic analysis makes the important distinction between 'neutral' and non-neutral' technical change. The former may...be defined as a change in which there is a shift in the production function but for which the capital-labor ratios remain constant. Non-neutral change...may be either capital-using (labor-saving)--if the ratio of capital to labor employed in the production process rises--or labor-using (capital-saving)--if the ratio of capital to labor employed in the capital-labor ratio falls. The significant point is that if factor prices remain constant, technical change which is labor-using increases the relative income share of labor, and capital-using technical change increases the relative share of capital.

Relative to other types of inputs entering into an agricultural production technology, the use of chemical inputs such as fertilizer implies an increase in both the capital/land and labor/land ratios as well as large increments in the level of management required for efficient use of these inputs. While fertilizer is a key input in increasing yields, this input's potential for increasing yields is not likely to be completely realized unless used in combination with improved (fertilizer-responsive) seeds, herbicides, pesticides, and various cultural

Table 18. A Classification of the Factor Bias and Potential Yield Effect of Inputs to Agricultural Production Technology (Adapted from Martinez, 1973:27).

Changes in Factor Ratios[a]	Mechanical	Biological	Chemical	Agronomic
Capital:Land	++	+	++	+
Labor:Land	--	0	++	++
Capital:Labor	++	+	0	-
On line management:Land	--	0	++	++
Staff management:Land	+	0	++	+
Changes in yield per hectare	0	+	++	++
Examples	*Tractor *Harvester	*Hybrid Seeds	*Fertilizers *Pesticides *Herbicides	*Cultural Practices *Management Practices

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a. The direction in which the factor ratio would change is indicated in each cell of the table as follows:

0 = no change
+ = small increment
++ = large increment
- = small decrease
-- = large decrease.

and management practices (cmpr. Panse and Singh, 1966:129; Atkinson and Kunkel, 1976:111). As Schutjer and Van Der Veen (1976:8) report:

> [HYVs] in combination with fertilizer require increased weed control and possibly more insect and disease control. ...one study by [the International Rice Research Institute] of farms growing HYV rice found a closer relationship between severity of weed infestation and level of fertilizer input than between yield and fertilizer input.... Further IRRI studies confirm the fact that high levels of fertilizer input make rice plants more susceptible to disease and insects.... Thus, the combination of increased fertilizer use and early HYV varieties that were not resistant to common plant diseases and insects resulted in a need for greatly improved management practices.

Since agricultural production technology (e.g., HYVs) is not static but continues to change, thereby requiring continuing adjustment of the inputs entering into production and marketing, the importance of the farmer having a high level of management ability is magnified. While fertilizer, even as a component of HYV technology, is widely recognized as being scale-neutral, divisible, and potentially yield increasing, the value of this input is viewed quite differently by farmers in varying circumstances and having varying abilities in farm management decision making. Such perceptions or evaluations are not intrinsic to fertilizer as an input or to the practice of using fertilizer but rather depend on the agronomic, economic, and sociological conditions prevailing in the environment in which the farmer makes production and marketing decisions. However, as Fliegel and Kivlin (1966b:237) have stressed, "much detailed work remains to be done to determine which attributes are relevant under given circumstances." Ideally, research along such lines would facilitate identification of the kinds of technology that would be appropriate to the needs, resource base, and preferences of smaller farmers and, thereby, be more likely to be favorably perceived and quickly adopted by such farmers.

An example of such research along these lines is proposed in Pinstrup-Andersen and Diaz (1975) and empirically applied by Pinstrup-Andersen, et al. (1976) who combined agro-economic analysis and agro-biological experiments to generate information on the kinds of technology that would be appropriate for the small farmer in Colombia. The agro-economic analysis provides estimates of the farm area affected by each of several yield constraints (e.g., extent of crop damage from a particular disease), estimates of yields and yield losses due to each variable, and quantification of the impact on yields of the various yield-reducing variables which have been identified as operating at the farm level.[40]

Data for the agro-economic analysis are obtained by a specially trained multidisciplinary team which observes farm-level conditions and interviews a panel of farmers. This team normally makes several visits to each farm. The data generated through observations and interviews are used to set up various agro-biological experiments which provide estimates of the yield-reducing impact of the various conditions (problems) identified in the survey. The various statistical procedures used in analyzing the data focus on describing the production process in terms of constraints, activities, and performance, and estimating the impact on performance of changes in constraints and activities. Specifically, estimates are made of:

1. Factors influencing the farmer's decision-making process for choosing a cropping system and adopting new technology;

2. Net returns from each principal cropping system;

3. Production costs and labor absorbed by production activity;

4. Contribution of each of the principal resources to net returns; and

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[40] The reader should note two points of clarification. First, the objective of the methodology suggested in Pinstrup-Andersen and Diaz (1975) and Pinstrup-Andersen, et al. (1976) is to use information about yield-reducing factors as a basis for identifying the technologies needed by farmers. Thus, the methodology does not assume that there is some "improved" technology which farmers should have adopted. Second, the approach taken by the International Rice Research Institute to study constraints on yields assumes that there is a technology (e.g., a new rice variety) that may be designated as "improved" and then attempts to identify what yield-reducing factors exist at the farm level with that technology or why the technology did not increase yields as much as expected. Detailed reports on this research approach are available in Barker and Anden (1975), Herdt and Wickham (1975), IRRI (1977, 1979), and De Datta, et al. (1978).

5. Economic loss caused by each of the agro-biological and ecological factors and potential payoff from alternative lines of research directed at solving identified problems.

Information such as that provided by these kinds of data is helpful in describing the environment in which the farmer makes his decisions. It should also provide signficant clues regarding the attributes which should be designed into a technology and the way in which the farmer is likely to respond to that technology.

A Typology of Innovation Attributes

Moulik, et al. (1966) found in north India that the farmer's knowledge about and attitude toward the use of nitrogenous fertilizer was directly related to his adoption of this fertilizer. As is illustrated in Rogers and Havens (1961), a farmer's attitudes toward an object are in part influenced by his knowledge or beliefs about that object. Thus, a farmer's favorable or unfavorable attitude toward fertilizer use is, to a considerable extent, influenced by his beliefs regarding fertilizer and the practice of using fertilizer. As discussed above, various researchers have examined the impact which beliefs about or perceptions of an innovation have on the rate of diffusion of that innovation. More specifically, studies in this area have focused on the perceptions which farmers have of various attributes of recommended innovations. There is yet no consensus regarding the number of an innovation's attributes that significantly influence a farmer in making his decision whether or not to adopt that innovation. Indeed, Katz, et al. (1963) even go so far as to say that "nobody is quite sure what dimensions of an item are relevant." However, a review of available evidence in the literature suggests that at least five attributes may be important from the farmer's point of view--observability, compatibility, profitability, reliability, and trialability. Various data on adoption of fertilizer use and related agricultural innovations by farmers in the developing countries are now reviewed to illustrate the impact which each of these innovation attributes can have on adoption.

Observability is the degree to which a farmer is able to see the results of having used an innovation. The importance of observability in influencing farmers to adopt a new technology was reflected in Rahudkar's (1958) study of the impact of fertilizer extension programs (e.g., demonstration plots) on Indian farmers. Rahudkar (1958:134) found that a "comparatively small number of cultivators see these demonstrations at the stage when differences in crop growth are very obvious." Morever, he observed that the demonstrations were visited and their purpose understood by only a few farmers and that the demonstrations had not been "as impressive as they should be."

In a Philippine study of 390 farmers, Feliciano (1964:11) found that "fertilizing is one practice which has been *highly* accepted in the barrios," with more than 80% of the farmers having used fertilizer *at one time or another*. For any particular time period, approximately 50% to 80% of the farmers had adopted the innovative elements of fertilizing in terms of the kind and amount of fertilizer used in various types of soil. Among the factors directly or indirectly influencing those farmers who did use fertilizer was the proven effectiveness of the practice (cited by 4 out of 10 farmers)--"the technician obtained quick and good results at the demonstration lot"; "the cooperator had high yields in his trial planting"; and "I saw the high yields."

Feliciano further sought to identify the reasons farmers had rejected 2/3 of the farm innovations introduced by extension workers. Seen or proven ineffectiveness of the practice was cited by 5 out of 10 farmers--"the hybrid corn seeds did not germinate"; "the plants were attacked by pests", and "it [the rice variety] lodged and had poor yields." Approximately 6 out of 10 farmers cited that the innovation was not better than existing practices. Relevant criteria in making such a judgment were taste and consumer's preferences in the market, production costs and demands on time and skills, and resistance to pests. To cite one example, the native corn was judged to taste better than the hybrid corn which also was viewed as being harder to plant, placing a higher demand on time and skills, having higher costs, and rating lower in consumer preferences. Thus, observability as a perceived attribute is seen to be interrelated with the perceived attributes of compatibility and profitability which are discussed further below.

The adverse influence of inadequacies in the observability of a net return from using fertilizer is reflected in Rogers and Niehoff (1967:7) review of bottlenecks in the diffusion of agricultural innovations in eastern Nigeria. On the basis of a survey of over 448 leaders in 71 eastern Nigerian villages, Rogers and Niehoff (1967:12) concluded that: "Fertilizer has been used by many farmers without adequate knowledge as to how much and with what crop it was to be applied, and results have often been either nonconvincing or even negative. ...negative demonstrations in the farmers' fields cause them to discontinue the new practice."

Rogers and Niehoff report that 3% of the farmers had discontinued the practice of using fertilizer and that this percentage was higher than that for 11 other innovations investigated, with the exception of poultry which was also discontinued by 3% of the farmers.

Compatibility is the degree to which a farmer perceives that use of an innovation is consistent with his needs, values, and past experience. In a practical sense, compatibility includes the degree to which a farmer perceives that an innovation is consistent with his farm's cropping system. Whether an innovation has an advantage over the technology currently used by the farmer cannot always be completely decided on the basis of conventional agronomic and economic criteria. Thus, for example, use of fertilizer increased among those farmers in Sierra Leone who adopted Radin China 4 (a rice variety more responsive to fertilizer than traditional rice varieties) because of the relative advantage of this variety for the life style of the farm family. Specifically, Isaac (1971:76-77) reports that:

> All of the participants in the Mando Chiefdom program in 1967 reported that the taste and texture of Radin China 4 is as good as, or better than, the taste and texture of their traditional varieties of both swamp and upland rice. Several also stressed that Radin China 4 preserves its flavor and texture after cooking to a much greater extent than does their native rice; this reduces the woman's work, because with Radin China 4 a woman can prepare the morning meal the night before, and then simply reheat it in the morning.

The importance of taking "family needs" into account in decision making about whether to use a new technology is reflected in Peters' (1973) study of farmer nonparticipation in the Puebla Project in Mexico. Peters suggests that an important factor in explaining farmer nonparticipation in the project is the farmer's capacity to produce the "Minimum Security Corn Production" (MSCP), i.e., the quantity of corn in kilos/family necessary to fullfill corn needs of an average family during 1 full year. According to a survey to evaluate the Puebla Project in 1971, an average family had between five and six members whose diet consisted principally of corn foods and beans.

On the basis of a random sample of farmers in two Puebla villages (Coltzingo and Nexteteclo), Peters estimated that the MSCP is approximately 200 kilos/person or 1100 kilos/family; thus, the average family needs, after production costs, a net of 1100 kilos. Analyzing data on farmer nonparticipation and farmer capacity to produce the MSCP in each of the two villages, Peters found in Coltzingo, where the percentage of participants had decreased from 30% to none during a 3-year period, that 89% of the nonparticipants were already capable of producing the MSCP. On the other hand, in Nexteteclo, where the percentage of participants had increased from 13% to 37% during the same 3-year period, only 36% of the nonparticipants were capable of producing the MSCP. These data, Peters suggests, tend to support the hypothesis that the farmers who were not participating in the Puebla Project were already producing at the output level of the MSCP and, consequently, were less motivated to participate. In contrast, those farmers who were falling short of the MSCP were, in effect, willing to try anything that might increase their productivity. Additional support for the contention that many of the Puebla farmers were primarily concerned with maintaining output to meet subsistance needs is reflected in the fact that there was no appreciable change in the number of farmers not selling a part of their corn harvest between 1967 (61%) and 1971 (60%). Thus, Peters contends, farmers were concerned first with MSCP and not production for commercial marketing.

Similarly, in a study of Thai farmers, Kolshus (1972:183) found a significant correlation between the proportion of the rice production which is marketed and the rate of fertilization, suggesting "that different production goals exist in [the] sample. Farmers who are market oriented, as compared to consumption sufficiency oriented, are more likely to use higher rates of fertilization." Accordingly, Kolshus (1972:183) notes:

> Percentage rice crop sold was also significantly correlated with yield per rai.... There are, therefore, good indications that market orientation leads to a more intensified agriculture, and that conversion of rough yield estimates to specific measurements of weight and value, makes the return of fertilizer more visible to the farmer, thus changing his perception of the profitability.

Profitability is the degree to which a farmer perceives that, in comparison with the technology he is currently using, use of an innovation will enable him to obtain a greater net benefit. The impact of profitability on the rate of diffusion of an innovation was well documented in Chapter II's review of economic approaches to diffusion research. The following data provide additional supporting evidence.

In a study of farm practice adoption by full-time farmers in selected Philippine barrios, von Oppenfeld, et al. (1962:26) identified a variety of reasons given by farmers for adopting or not adopting a number of specific farming practices. The most frequently mentioned reasons for adoption were: expectations of higher yield, income, or profit (47%), physical characteristics of the plants or animals (17%), and lower incidence of pests and diseases (12%). While 41% of the farmers cited lack of resources such as funds, materials, and services as reasons for nonadoption, another 33% gave such reasons as no confidence in higher yield or income, higher incidence of pests and diseases, and the greater time and effort involved. While the data reported by von Oppenfeld are not broken down with specific reference to fertilizer, one specific conclusion did emerge with respect to adoption of fertilizer use, namely, that a farmer's recollection of the lodging of his rice crop and accompanying low harvest, induced because of the fertilizer he had applied, would likely be a powerful deterrent to continued use of fertilizer (von Oppenfeld, et al., 1962:27). Of course, since the time the von Oppenfeld study was conducted, research at the International Rice Research Institute has developed high-yielding rice varieties which are less susceptible to lodging.

In a study of adoption of new high-yielding rice varieties among 155 randomly selected farmers in three Philippine municipalities, Liao and Barker (1969:17) found that: "Almost all of the adopters reported that the most important factor was the expected high yield from the new varieties." However, realizing that rice millers were discounting the price of IR-8 because of its reported low milling quality, inferior eating quality, and inability of many farmers to dry, store, and market the early maturing rice grown in the wet season, some farmers stated that they planned in subsequent growing seasons to reduce the area planted to IR-8. Since the technology used to grow IR-8 requires a threefold increase in the rate of application of fertilizer over the rate used on traditional varieties, the perceived inadequacy of the IR-8 rice variety and the subsequent decision to reduce the area planted to IR-8 imply that farmers would proportionately reduce their level of fertilizer use.

Another example of the importance of profitability is seen in Atkinson and Kunkel's (1976) study of the progress of the 'seed-fertilizer revolution' in the Philippines. While about half of the lowland rice area in the Philippines was planted to HYVs in the 1969-70 crop year, 1/3 of all the farmers using HYVs were not using commercial fertilizers. And those farmers who were using fertilizer in irrigated areas applied an average of 32 kilograms per hectare of nitrogen plus phosphorus, about 1/3 of the recommended rate for irrigated HYVs. Why was the level of adoption of fertilizer use not higher?

Analysis of data collected in a survey of farmers revealed that the calculated profitability of fertilizer use and the optimum application rate were lower than had previously been estimated. On the one hand, the estimated response of HYV rice yields to increased applications of fertilizer obtained by farmers was lower than "the widely used trial responses obtained by the United Nations Development Programme--Food and Agriculture Organization (UNDP-FAO) in experiments in the Philippines" (Atkinson and Kunkel, 1976:vii). On the other hand, farmers who were surveyed reported paying appreciably more for fertilizer than published market prices. Thus, the estimates of the profitability of using fertilizer, as calculated from the survey data, were lower than the previous estimates which had served as a basis for formulating recommendations. Atkinson and Kunkel (1976:vii) conclude that:

> The observed fact that most farmers did not follow Extension Service recommendations may reflect their feeling that they would get a lower fertilizer-yield response under farm conditions than under the conditons assumed when the recommendations were formulated.

Indeed, further data analysis revealed "that, on the average, those farmers who used fertilizer came fairly close to an optimum usage" (Atkinson and Kunkel, 1976:viii). The two authors also point out that Philippine farmers lack the degree of control that is exercised in the International Rice Research Institute experimental plots where highly advanced management is evidenced in such areas as timing of operations and control of water, pests, and diseases. In short, "IRRI spares no cost to ensure controlled conditions, which may not be economical or even possible for farmers" (Atkinson and Kunkel, 1976:viii). Farmers are aware of such differences between their own farm plots and the experiment station's research plots. This awareness prompts them to discount the return promised for the recommended innovation. When such discounting takes place, the farmer is likely to consider the profitability of using the innovation to be less than that 'promised' by the extension worker who urged the farmer to adopt the innovation.

Van Der Veen (1975) similarly reports that substantial variation in the prices the farmers receive for their paddy rice in the Philippines has resulted in a similar variation in the profit-maximizing levels of use of fertilizer, pesticides, and other inputs.

Among those not using fertilizer in a sample of farmers in western Nigeria (Williams, 1968), 34% indicated that they didn't believe the practice would result in more income. Of those using fertilizer, 74% felt that they could make more money by using fertilizer. The importance of the profitability of using fertilizer as a factor affecting the farmer's decision to continue using this input was reflected in the fact that 28% of the fertilizer users had more than doubled their income by using fertilizer, 10% had increased their income by 1/2 to 3/4, 17% by 1/4 to 1/2, and 13% by 1/4.[41]

The importance of profitability in explaining variation in the quantity of fertilizer used by farmers is further illustrated by data (table 19) from a study of management decisions on 50 small farms in Taiwan (Hsieh, 1966). The large number of farmers increasing the use of compost rather than chemical fertilizer is explained by Hsieh (1966:17) as follows:

> ...since compost can almost perfectly substitute for chemical fertilizers, and since most farmers considered the fertilizer-paddy barter ratio as unfavorable and...did not have much surplus rice for making such an exchange, [farmers] had to produce more compost manure to supplement or substitute for chemical fertilizer.

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[41] Regarding those farmers who lost money using fertilizer, 31% of the sample, Williams (1968:27) suggests that: "It is very likely that many farmers who lost money on using the improved practices either did not follow the recommended practice closely or the extension agents who were one of the chief sources of information did not give them sufficient technical advice. It is also possible that many farmers lacked financial ability to follow the practice throughout many stages of its application."

Table 19. Variations in the Quantity of Fertilizers Used in the Past 3 Years on Small Farms in Taiwan (Hsieh, 1966:17)[a]

Variations	Compost	Chemical Fertilizer
Increase	19	5
Decrease	3	4
Irregular	1	3
Subtotal	23	12
Unchanged	27	38
Total	50	50

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[a] Data from survey made in the Spring of 1961.

When asked how they would respond to an increase in the price of chemical fertilizer, 70% of the farmers interviewed said they would increase the production of compost, 13% would purchase more night soil, 10% would increase cultivation of green manure crops, and the remaining 7% would resort to planting crops which do not require as much fertilizer.

Reliability is the degree to which a farmer is convinced that use of an innovation will consistently produce a certain level of output. The concept of reliability is closely related to the concepts of risk and uncertainty (cmpr. Myren, 1964; Hiebert, 1974; Binswanger, 1977). The more consistently the farmer perceives that an innovation will produce a minimally required output, the higher the reliability of that innovation becomes in the eyes of the farmer. Most simply stated, from the farmer's point of view, a reliable innovation is a consistent innovation, one on which he can depend for provision of the minimum output required in order to feed his family and, if possible, have some surplus to sell in the market. Innovations which the farmer does not believe will consistently help him to subsist or "turn a profit" are objectively less likely to produce the requisite minimum output and more likely "to produce" negative returns, i.e., the physical yield and/or the monetary return are likely to be less than under the technology currently used by the farmer. In either case, use of such an innovation would involve an increased probability that the quantity of output produced will be insufficient, thereby placing the smaller farmer and his family closer to the subsistence level or possibly even below it.

There are, of course, many potentially intervening variables which could influence the probability that such an event would occur or the farmer's perception of the likelihood that such an event would occur and, thereby, influence the farmer's perception of the reliability of the innovation in question. These variables include:

1. The physical productivity of the innovation when used on the farmer's land, particularly as a function of environmental variables such as rainfall;
2. The market prices for output, labor, and other inputs;
3. The financial condition of the farmer and his family, including capital, liquid assets, and income from off-farm employment; and

4. The number of persons in the farm family who are directly dependent for susbsistence on the farm's output, the age and sex composition of the family members, and the health of each in terms of existing nutritional and morbidity levels.

It is beyond the scope of this monograph to specify the exact manner in which these variables or the farmer's perception of them may influence his evaluation of an innovation's reliability, i.e., the probability that adoption of the innovation will consistently produce the required level of output.

What does need to be emphasized, however, is the idea that some combination of the four listed variables may significantly influence the farmer's perception of an innovation's reliability. It also should be emphasized that the farmer's perception of an innovation's reliability may be a more precise means of expressing what is conventionally referred to as "risk." To be clear, "risk" is not an attribute of an innovation; on the contrary, "risk" lies in "the eyes of the beholder," in the present case, the farmer. In other words, the farmer's perception of an innovation's reliability is, in effect, the risk the farmer believes to be involved in adopting an innovation. The farmer who does not adopt an innovation because he perceives it to be "too risky" is basically not adopting because he perceives the innovation to not be sufficiently reliable.

The possibility of further specifying the relationship between reliability and adoption is limited by the fact that this concept has not been used in previous empirical research. However, since we have seen reliability to be the converse of risk, an examination of selected empirical findings bearing on the relationship between risk and adoption would be appropriate, particularly in light of de Janvry's (1972:1) observation on risk and fertilization:

> Particularly in nonirrigated farming, the physical outcome of fertilization is stochastic since it depends upon uncontrollable climatic events. The economic return from fertilization is, hence, stochastic; and it is of importance to assess as precisely as possible the level of risk that farmers assume when they invest in fertilizers. This is especially true in many less developed countries where farmers face relatively unfavorable input-output price ratios, thus working with narrow profit margins. These farmers in addition usually do not have the financial resources to bear

> losses in bad years, since fertilizers are purchased on short-term credit without insurance schemes that would allow them to spread over successive crops the risks assumed in any one year. Finally, farmers may be only in the early process of adopting fertilizers as a new technology, and a failure to assess the risk they have assumed in using particular fertilizer doses may lead to serious setbacks in the spread of technological changes.

Kolshus (1972:187), in studying the modernization of rice farming in northeast Thailand, found that risk, as measured by average annual flood and drought destruction, was negatively and significantly related to kilograms of fertilizer used per rai by the farmers sampled. Another measure of risk--how much of the planted area was harvested in the previous year--was not found to be related to the fertilizer application rate.

Kolshus also attempted to measure the concept of "ability to bear risk" with such variables as net worth, consumption sufficiency ratio (CSR) (the ratio between total rice produced and the household food requirement), and percentage of crop diversification. Since none of these three variables was found to be both positively and significantly related to the rate of application of fertilizer, Kolshus (1972:177) rejected the "hypothesis that risk aversion due to capital shortage, proximity to subsistence, or dependence on a single crop serves as a deterrent to high application rates...." It should be pointed out that Kolshus (1972:179) raises the possibility that the CRS may not be a good measure of ability to bear risk but rather is more closely linked to market orientation. The CSR was found to be "positively and highly correlated with percentage of rice production sold (r = 0.564), a market orientation variable which is positively and significantly related with rates of fertilization." Yet the CSR was also found to be "significantly and negatively correlated with rates of fertilization" in a separate regression model (Kolshus, 1972:177). This set of relationships (correlations) is represented in figure 3.

Kolshus (1972:181-183) offers three possible explanations which, alone or in combination, may shed light on the apparent inconsistency in figure 3:

> 1. If the alternative [to producing rice with fertilizer] is to purchase rice in the market at a price reflecting labor costs and marketing charges, a relatively poor farmer who is having difficulties

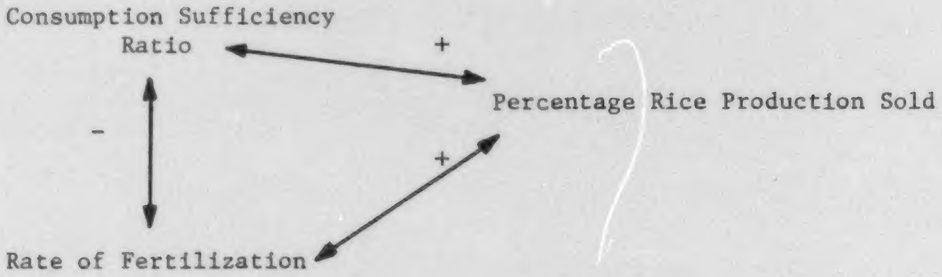
Consumption Sufficiency
Ratio
+
Percentage Rice Production Sold
-
+
Rate of Fertilization

Figure 3. Diagrammatic Representation of Relationships Between Rate of Fertilization, Consumer Sufficiency Ratio, and Percentage Rice Production Sold (Kolshus, 1972:177, 179)

> meeting his household's food requirements, may correctly perceive that he is better off using fertilizer to increase his own yield than to buy rice in the market. This would especially be the case if there were underemployed labor resources in the household.
>
> 2. If [the farmer] is not market oriented and his family is well provided for, the inducement to intensify the production by using fertilizer is absent, and a lower rate of fertilizer use would be rational behavior given a consumption sufficiency goal.[42]
>
> 3. ...since education, knowledge, deliberation, progressive attitudes and social position were...correlated with economic assets and the consumption sufficiency measure,...the low rate of fertilizer application on [the] part of the better-off farmers [may be] a result of a rational decision based on their perceptions of the limited relative economic advantage of fertilizer use. The more disadvantaged and less deliberate individuals may be using higher rates of fertilizer due to susceptibility to social pressures because of ignorance and desperation, because it is the *only way*, albeit a risky one, of meeting basic food needs.

It is apparent that Kolshus' study raises more questions than it answers about the relationship between risk and adoption. Since he is limited to speculations and the associated introduction of additional variables in order to explain his study's findings, his work reemphasizes the need for a model that clearly specifies the relationships between adoption, reliability (or, conversely, risk), and the numerous, potentially intervening variables suggested earlier in this section.

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[42] Kolshus notes that this interpretation is consistent with Greene's (1971:44) conclusion that Thai "farmers with the most advantages appeared to use fertilizer on smaller proportions of their land than the more disadvantaged farmers."

The importance of such potentially intervening variables is seen in Colmenares' (1975a:76-79) discussion of risk in relation to adoption of hybrid seed and fertilizers among low, medium and high altitude corn farmers in Colombia. Colmenares recognized the following components of risk: "previous experiences about physical factors such as the productive capacity of the land and climatic conditions," "evaluations of specific events whose odds are (subjectively or objectively) known," "economic constraints or ability to absorb the costs of alternative management decisions," "dependency upon the productive results of a given agricultural season," "the farm's physical endowment" and "the farmer's past performances." As a measure of the farmer's "risk-averting decisions," Colmenares used the particular type of corn enterprise practiced by the farmer, i.e., corn interplanted with other crops or cultivated in a single stand. Additionally, farmers were asked to estimate output from their best field for both average ("normal") and less than average ("bad") agricultural years, and to give the number of times in a 10-year period they actually expected the estimated levels of output to occur. These data were used to construct an "index of expectations" of yield variability.

Empirically, for the sample of farmers in the low altitude zone, Colmenares (1975a:110) found that the beta coefficients for the regression of adoption of fertilizer use on type of corn enterprise, although positive as predicted, were not statistically significant. On the other hand, a statistically significant negative (as predicted) relationship was found between the "index of expectations" of yield variability and adoption of fertilizer. Additionally, in the low altitude region, the type of corn enterprise was found to be positively and significantly correlated with the quantity of nitrogen applied, while variations in yield were negatively and significantly correlated with the quantity of nitrogen applied. Although these relationships were not found to be statistically significant for the sample farmers in the two higher altitude regions, the fact that they were found to be statistically significant in the case of farmers in the low altitude region provides further support for the hypothesis that there may be important intervening variables which are influential in determining the relationship between reliability (risk) and adoption.

Several other studies of risk also reemphasize the idea that the relation between risk and adoption will depend on the particular intervening variable which is brought "into the equation." For example, Roumasset (1973) concluded that risk was not a key variable in determining the level of use of nitrogenous fertilizer by Philippine farmers. While Roumasset's model takes into account "damage states," levels of solar radiation, rates of application of fertilizer, and an estimate of risk preference (risk sensitivity index) in order to predict levels of use of nitrogen, his study was limited to rice grown under irrigated conditions and was not designed to explain or predict either the time of initial adoption of fertilizer use or the quantity of fertilizer initially adopted (used) by the farmer.

Similarly, Cancian (1967, 1972) hypothesized a curvilinear relationship between stratification and adoption. His analysis suggests that the relationship between risk and adoption may be influenced by a number of intervening variables: the divisibility of risk in the sense of ability to divide inputs (investments), knowledge about the requirements of the technology in question, the resource position of the potential adopter with regard to subsistence requirements, the distribution of these resources among individuals, and the relative importance of potential loss in rank (social position).[43]

Another example is seen in Moscardi's (1975a, 1975b) work to develop a methodology for studying attitude toward risk among farmers in the Puebla Project in Mexico. The farmer's aversion to risk is seen to be a function of the socio-economic and structural characteristics of the farm family, including such variables as human capital (age, schooling, family size), nonhuman capital, and organizational power (participation in a community group). On the basis of subsequent empirical work along these lines, Moscardi and de Janvry (1977:715) report:

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[43] Frey, et al. (1979) report that their data on 173 farmers from 10 villages in the Punjab Province of Pakistan fail to support Cancian's upper-middle-class conservative thesis. Gartrell (1977: 318) reports that: "Analysis of data from samples of cultivators in 84 agrarian communities in Andhra Pradesh, India, found little support for Cancian's theory that rank inhibits risk-taking, even under conditions specified as necessary for such effects." Based on further analyses of these data, Gartrell and Gartrell (1979) found that, at higher levels of status, awareness of an innovation is translated into trial of that innovation at a higher rate. See also Clawson (1978) and Boyd (1980).

> Estimation of risk aversion for a relatively large sample of [Puebla] farmers...shows that risk aversion is indeed responsible for substantial differences between the demand for fertilizer without risk and actual demand. Risk premiums are high, discouraging the use of high rates of fertilizer under safety-first behavior.

From the risk-related literature reviewed, it would seem to be a fair conclusion that the final or definitive approach to the exact relationship between risk and adoption has not been developed yet. Additional research oriented to specifying the relationship between risk and adoption is needed to clarify the influence of intervening variables, and to specify ways in which risk can be reduced for the farmer. Stated in terms of the reliability concept, such additional research should identify those factors which determine the farmer's perception of the reliability of a technology or an innovation and ways in which both actual as well as perceived reliability can be increased. As Wolgin (1975:625) concluded from a study of risk and resource allocation in small-farm agriculture in Kenya:

> ...it is clear that risk aversion plays a very important role in farmer behavior; farmers are willing to grow high risk crops only if they get a higher payoff in expected return. Moreover, such aversion may help explain why farmers are interested in multicropping.... By producing a [variety] of crops they can get the same range of expected return at lower levels of risk, as they would if they grew only one crop at a much higher risk level...(emphasis added).

Wolgin (1975:630) suggests that a "government insurance program" would lower risk: "If farmers were able to obtain credit not only for purchase of modern inputs but also to insure survival in the face of adverse weather conditions, they would be more willing to take risks."

These various empirical reports suggest that the farmer's perception of an innovation's reliability or, conversely, the risk involved in using an innovation, is likely to be an important factor in determining whether or not the farmer adopts that innovation. Although considerable research has already been conducted to improve our knowledge about the influence of risk in decision making (cmpr. Dillon, 1976; Roumasset, 1977), this area of research continues to be riddled with disagreement regarding the definition and utility of such concepts as "risk," "perception of risk," "risk aversion," "risk preference," etc. It thus appears that much research remains to be done to clarify the relationship between risk and the adoption of an innovation.[44]

Finally, while an increasing number of studies have focused on risk in relation to adoption and farmer decision-making, it is of interest to note that few, if any, of these studies have empirically explored the possible implications for diffusion research of Friedman and Savage's expected-utility hypothesis about decision-making under conditions of risk (cmpr. Friedman, 1968; Peacock, 1972; and Mason and Halter, 1980). This hypothesis specifies the conditions under which the rational individual will either gamble or insure.[45] Simply stated, the hypothesis is that the individual with a diminishing marginal utility for money (i.e., an individual who places increasingly smaller value on having increasingly greater amounts of money) will maximize his expected utility by insuring, while the individual with an increasing marginal utility for money will maximize his expected utility by gambling.

However, if one thinks for a moment about the expected-utility hypothesis, one recognizes that many factors could affect an individual's expections or perceptions and, thereby, the individual's response to uncertainty and risk, i.e., to gamble or to insure. Such factors could include the size of the capital stake involved, the individual's income and savings, the length of time involved, or even the individual's perception of the relative health or prosperity of the economy (e.g., the outlook for favorable weather).

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[44] Although not specifically addressed to explaining diffusion-related phenomena (e.g., the decision to adopt), a number of approaches to research on risk are being investigated. Examples of studies in this area include de Janvry (1972); Roumasset (1973, 1974a, 1974b, 1974c, 1975, 1976) on risk neutral and lexicographic safety-first models; and Anderson (1973, 1974, 1976), Hardaker and Tanago (1973), O'Mara (1971, 1972, n.d.), and Scobie, *et al*. (1976) on stochastic dominance models. The research approaches used by Roumasset (1976) and Scobie, *et al*. (1976) to study risk are briefly reviewed in the appendix. See also Jedlicka (1977, 1979b), Binswanger (1978), Binswanger, *et al*. (1978), and Jodha (1978).

[45] If an individual gambles, he is betting or paying some amount of money X that he will be the winner of some quantity $Y >$ (X = the amount bet). If an individual insures, he is paying some amount of money X to secure in the event he loses some amount Z, where $Z > X$, that the recipient of the payments X will reimburse the individual some amount Z', where $X < Z' \leq Z$.

Moreover, while the Friedman and Savage hypothesis (1) recognizes that an individual's utility function for money can have both a portion where marginal utility is increasing and a portion where marginal utility is decreasing, and (2) predicts how the individual will respond under the respective portions of such a function, the hypotehsis does not specify the conditions under which an individual with such a function will move from that portion of the function where the marginal utility is increasing (or decreasing) to the portion where the marginal utility is decreasing (or increasing). This is a serious shortcoming in the Friedman and Savage hypothesis which considerably limits its explanatory power. However, in view of the considerations discussed here with reference to the expected-utility hypothesis, it would appear that the hypothesis is one that would provide an interesting point of departure for designing future research on adoption of fertilizer use under conditions of risk and uncertainty, even though its quantification and empirical testing would be a difficult task.

Trialability is the degree to which the farmer can experiment with an innovation on a limited basis on his own farm. While fertilizer as an input is theoretically perfectly divisible, there may be a number of intervening variables which make it more difficult for the farmer to conduct a trial of fertilizer use on his own farm. These variables or factors may not be attributes of the fertilizer per se, but they may nevertheless impede the farmer's favorable perception of the trialability of fertilizer use. Holden (1972:465-466) summarizes many of these factors as follows:

> The adoption of the practice of using a chemical fertilizer...requires among other things either capital or credit. The acquisition of these is never easy and may put one into the hands of money lender or the bank which can be equally demoralizing.... The adoption of this practice also [requires] the establishment of a relationship with others in order to acquire the fertilizer. All these changes are required before the practice can be "adopted." . . .
>
> To allow the adoption of...fertilizer..., a certain series of activities has to be guaranteed. Fertilizer of the right kind for the soil, the crops, and the climatic conditions, and in adequate amounts has to exist. It has to be shipped into the area where it is to be used.... It has to be stored in conditions that

> will not lead to its deterioration or destruction.... And the whole operation needs to be financed. Then, one requires the personnel to handle all these activities and to do so in such a way that the fertilizer is available to the farmer at the right time of year. If it is even a few days late it may be of no use. In most underdeveloped societies it would be a fairly safe assumption that any one or all of these things are missing or not operating. . . . ...the assumption is commmonly made that the infrastructure for the adoption of the practice in question exists and is operating. In actual fact, the failure to adopt may be the failure of part or all of the infrastructure....

In a similar vein, Burke (1978:3) writes that the new technologies recommended to farmers

> ...involve far more than an increase in output in response to new seeds and increased fertilizer inputs. The application of fertilizer at one or more times during the growing season increases the demand for labor. Similarly, the high levels of fertilizer encourage weed growth which must be dealt with either by hand weeding or by chemical herbicides. Finally, the effectiveness of fertilizer is substantially enhanced by the presence of irrigation. Thus the new technology, as actually implemented, involves *a fairly complex transformation of the entire production process*. *While the seeds and fertilizers themselves may be perfectly divisible and therefore not subject to economies of scale in themselves, it is not so obvious that the technical production process is scale neutral when all factors are taken into account* (emphasis added).

Low trialability of fertilizer use was suggested by Aklilu (1976:201) as one factor which could explain the lag of Ethiopian tenant farmers in adopting this innovation in Bako, where a development project known as the Minimum Package Programme had

> ...a policy of setting the minimum fertilizer sale at 25 kg. - half a bag. This requirement affects tenants

> more than others since they are the group that have the smallest farm size and the least liquid asset[s]. The 25 kg. requirement also deprived them of the opportunity to personally test the performance of the new input in a smaller scale. . . . ...mention should also be made of the 25 percent downpayment requirement. Again, it is the pure tenants group that is constrained the most by this requirement.

Issac's (1971) study of a swamp rice development program in Sierra Leone provides further data illustrating the relationship between input divisibility or, more generally, trialability of a new technology and a favorable response by farmers to a specific innovation, use of Radin China 4 rice (a swamp rice). The change agent, a Peace Corps volunteer, rather than requiring that farmers plant a minimum of 1 acre and no more than 2 acres of the new rice variety, allowed each farmer to develop as little as 1/2 acre or as much as several acres. Accordingly, each farmer could adjust his participation in the program according to his aspirations, capability, and resource availability in terms of time and labor.

These observations suggest that trialability interacts with the farmer's perception of accessibility to inputs in determining whether he will adopt a particular innovation. In the case of fertilzer use, there are numerous changes which must occur in the agri-support system before the farmer can even decide whether or not to try fertilizer on his own farm. Obviously, if such changes have not yet taken place in a developing country or region thereof, namely an infrastructure to distribute credit, fertilizer, and information (on which fertilizer to use, how much, and how to apply it properly), then the smaller farmer is likely to conclude the innovation of fertilizer use is not readily trialable.

At the same time, it must be remembered that if an adequate infrastructure for distributing information, credit, fertilizer and other inputs (e.g., HYVs) exists, then the innovation of fertilizer use is more likely to be viewed by the farmer as having high trialability. If the farmer can obtain the amount of fertilizer required for an experimental trial or small-scale plot, then he can objectively test the crop's response to fertilizer under his own farm's conditions.

A Case Example: The Caqueza Project

Zulberti, et al. (1975) report a study of the adoption of a recommended technology for corn production by small farmers in the Caqueza Project in Cundinimarca, Colombia (see also Zandstra, et al., 1979 and IICA and CIID, 1975). Table 20 shows various data relating to differences between the existing and recommended technologies. Table 21 provides data on the levels of adoption of fertilizer use under the recommended technology.

The reader will observe in table 20 that, in terms of net revenue, the recommended technology (US $205/ha) was more profitable than the existing technology (US $58/ha). In view of this difference, why were the levels of adoption so relatively low? Various data and interpretations reported by Zulberti, et al. (1975) provide support for the hypothesis that the relatively low percentages of farmers adopting fertilizer use may be explained by deficiencies in the observability, compatibility, reliability, and trialability of the recommended technology.

With respect to observability, if the new technology was developed through experiments on the farmers' holdings, then possibly some of the farmers were aware of two deficiencies in the new technology. First, if the farmer applied less than 100 kg per hectare of fertilizer, the hybrid variety would yield less than the traditional variety. Second, if the farmer applied the recommended rates of fertilizer per hectare, 350 kg/ha, then he faced an increased probability that in any particular year his returns would be negative. Whether the farmer directly observed or heard about these shortcomings in the recommended technology, the technology's observability with regard to profitability and reliability was likely reduced in the eyes of the farmer. Additionally, some amount of deviation from the recommendations in regard to timing and rates of application may be attributed to the fact that these practices cannot readily be observed unless the potential adopter actually watches an adopter using the innovation in question. Finally, since any particular farmer's field may be subject to conditions which differ from those existing at the particular sites where the technology's recommendations were formulated, it is less readily observable that the recommended rates of application are appropriate to the farmer's particular holding(s). In other words, it is less readily observable to each individual farmer that the recommended rate would be the optimal rate for his particular farming situation.

With respect to compatibility, the extra labor required for the second fertilizer application came at a time which exactly

Table 20. Existing Technology and Recommended Technology for Corn in the Caqueza Project in Colombia (Adapted from Zulberti, *et al.*, 1975:3)

	Existing Technology	Recommended Technology
Variety or hybrid	Traditional	Hybrid[a]
Planting density		
Rows per ha	90	100
Hills per each 100 meter row	90	125
Plants per hill	3	3
Fertilization		
10-30-10 (planting)	0	200 kg/ha
Urea (1st application at planting)	0	25 kg/ha
Urea (2nd application at 40-50 days)	0	125 kg/ha
Pest Control		
Heliothis spp	No control	Control
Spodoptora Rugiperda	No control	Control
Agrotis spp	No control	Control
Production		
Average yield	907 kg/ha	2740 kg/ha
Standard deviation	660 kg/ha	1170 kg/ha
Net Revenue	US $58/ha	US $205/ha

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a. The recommended hybrid varies with altitude above sea level.

Table 21. Percentage of Farmers Adopting Recommended Technology in the Caqueza Project in Colombia
(Adapted from Zulberti, *et al*., 1975:8)

Fertilizer Practice	Existing	Recommended	Level of Adoption			
			Not Adopt	Less than Recommended	As Recommended	More than Recommended
10-30-10 (planting)	0	200 kg/ha	0%	65%	9%	26%
Urea:						
1st application (planting)	0	25 kg/ha	83%	4%	0%	13%
2nd application (40-50 days)	0	125 kg/ha	52%	43%	0%	5%

coincided with what was already the period of peak labor requirement in the region. Also, the recommended variety, a hybrid maize with a flint-type kernel, was judged by the farmers to be inferior to the regional variety (with a soft or floury kernel). This difference was considered by the farmers to adversely affect the palatability of native foods prepared from the hybrid maize.

With respect to reliability, an analysis of various economic aspects of the recommended technology revealed that while the new technology substantially increased production and income most of the time, it also

> ...increased the expected value of the loss function by 111 percent when total costs were used and an astonishing 1530 percent when cash costs for material inputs were used. Hence, another possible reason surfaces for why the corn farmer did not adopt the new technology...(Zulberti, et al., 1974:16).

With respect to trialability, the technology recommended by the Caqueza project was not one that could be easily used on a trial basis by the farmer. While any one input (e.g., fertilizer) was theoretically divisible, the farmer would benefit from a trial of the technology only if he used all of the technological package's recommended inputs. Thus, even though the farmer might be willing to try the technology on a 1/5 ha or 1/10 ha plot, he would still have to obtain all the necessary inputs (e.g., recommended seed variety, fertilizer, etc.). Additionally, if he wished to conduct a trial of the technology, then he was faced with the problem of calculating the proper rates of application for the size of plot on which the trial would be conducted. Even if the farmer is able to make this calculation, the additional work and time involved in developing this information is an added expense in terms of opportunity cost (the amount of earnings the farmer would realize if the time in question were to be used working in the most profitable employment available). If the relative advantage of the technology is weighed against this opportunity cost in combination with the technology's other disadvantages as discussed under reliability, compatibility, and observability, it would not be unreasonable for the farmer to decide that the best course of action would be to continue with his present technology rather than to conduct a trial on his own farm.[46]

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[46] It would also be the case that a trial of the recommended technology would require substantial change in the farmer's behavior, e.g., learning when and how to apply fertilizer, increased labor for fertilization, etc., thereby increasing the real cost of adoption.

CHAPTER V

OTHER RESEARCH APPROACHES

Chapters II through IV discussed a variety of approaches to research on the diffusion of an innovation. The present chapter reviews additional research approaches which, although they do not fit neatly into any general approaches previously discussed, nevertheless merit review and comment: the field experiment, tree analysis, and other multivariate analysis approaches.

THE FIELD EXPERIMENT[47]

Relatively few diffusion studies have employed the field experiment (cmpr. Bennett and Leonard, 1970; Brown, 1970; Spector, *et al.*, 1971). This approach combines certain aspects of the survey and the laboratory experiment. In order to conduct a field approach, the researcher must identify one or more innovations that would be beneficial for a specific population of farmers to adopt; establish "treatment" and "control" groups within the specified population; measure the dependent variable (e.g., adoption) in both groups prior to experimental manipulation; manipulate within the "treatment" groups one or more independent variables hypothesized to be related to the dependent variable (adoption); and measure the dependent variable in both groups after the experimental manipulation.

Several field experiments on the diffusion of innovations in Brazil, Nigeria, and India (Rogers, *et al.*, 1970) illustrate one application of the field experiment approach. These field experiments were designed to test the effect of prototypic communication strategies on innovation diffusion. Experimental manipulations included radio forums, literacy-reading classes, and community newspapers. In summarizing their findings about how to improve a change agency's effectiveness in diffusing innovations to farmers, Rogers, *et al.* (1970:8-13) conclude: "When change agents wish to identify their clients who are most receptive to innovations, they should look for clients who have literacy, more formal education, higher farm income, larger-sized farms, etc." It should be clear, however, from the evidence reviewed in the preceding sections, that such a strategy would be less than effective in reaching farmers who are relatively illiterate and uneducated and who operate smaller-sized farms. This raises the question of what would be a more effective approach to take in order to achieve an accelerated rate of diffusion of an innovation among smaller farmers. Two case studies illustrate that the potential range of effective strategies may be broader than that which is reflected in the strategy proposed by Rogers, et al. (1970).[48]

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[47] Tandon (1978) provides a review of fertilizer promotion programs in India. These programs emphasize intensive activity in a few locations, strength of technical content, coordination among different agencies, and media evaluation. Specific innovations in promotion include the Village Adoption Programme, block demonstrations, Integrated National Supply System, Technical Extension Programme, marginal farmer development, and fertilizer festivals. The caution which must be exercised in drawing conclusions about the impact of a fertilizer use promotion program is documented in Paddock's (1973:183-194) review of the Mass Fertilization Program in El Salvador.

Case Study 1: The "Do-It-Yourself Rice Kit"

A publication of the United States Agency for International Development (USAID, 1967) summarizes the Philippine experience with the "Do-It-Yourself Rice Kit"--a "package approach" that combined innovations in agricultural production technology (IR8 rice) and in the marketing of the technology's requisite inputs (e.g., fertilizers). The "Do-It-Yourself Rice Kit" was a package which contained sufficient inputs to permit the farmer to grow IR8 rice on a trial basis on 2,000 square meters (1/5 hectare). The kit included 6 kg of IR8 seed, 16.6 kg of Lindane (for stemborer control), 1 kg of Sevin (for leafhopper control), 44 kg of urea fertilizer (45% nitrogen), 1 kg of Alferin (rat poison), and one step-by-step instruction booklet printed in the farmer's dialect.

> The Filipino farmer had never had such a completely packaged opportunity before. He may have been able to get good seed...[but]...the proper credit was not available. Or a crucial input such as fertilizer may not have come on time, or the wrong kind of pesticide may have been furnished. The rice kit--a complete package--eliminated such logistic problems (USAID, 1967:13).

The "Do-It-Yourself Rice Kit" program was not reported by USAID (1967) as having been conducted as a field experiment; nor does the experience appear to have been formally or explicitly based on prior findings or methodology from research on the diffusion of innovations. However, it is clear that the "Do-It-Yourself Rice Kit" program does illustrate the potential influence on the diffusion of fertilizer use which a well-designed experiment could have empirically demonstrated. Specifically, the experience illustrates that the rate of diffusion of an innovation will be increased if the innovation in question can be developed and marketed in a way that enhances the innovation's observability, compatibility, profitability, reliability, and trialability in the eyes of the farmer.[49]

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[48] Other agricultural extension models of production education are reported in Benor and Harrison (1977) and The University of Minnesota Project in Chile (1971).

In terms of these attributes, particularly trialability, the "Do-It-Yourself Rice Kit" had the following positive features. Since the kit contained the proper amount of each input, the farmer had no need to purchase varying amounts of each of the inputs. The farmer was thus spared the effort of having to try to locate every input himself, as well as having to incur additional expenses during a time when it was more important that he have a chance to try on his own farm the IR8, fertilizer, and other inputs required by the new technology. The manner in which the inputs were packaged and the minimal investment required to obtain the kit gave the smaller farmer an opportunity to try the innovation on a small scale, thereby reducing the risk of a trial on his own farm. Not having to take time to convince farmers to purchase the various inputs or assist them in obtaining inputs, the supervising agricultural technicians (change agents) could concentrate their efforts on assisting the farmers to arrange credit for purchase of the rice kit and teaching them about the modern rice culture practices required to properly use the kit's inputs.

On the observability, profitability, and reliability attributes, the "Do-It-Yourself Rice Kit" had especially positive marks. Before the introduction of IR8, the average rice yield per hectare in the Philippines was less than 30 cavans. With IR8, the farmer would be able to harvest two to four times this amount. The economics involved in this comparison were reported by USAID (1967:6-7) as follows:

> Cost-benefit analyses show that ordinary rice grown by the old traditional method may cost as little as ₱200 per hectare (not including land rental) to cultivate. This usually yields an average of 30 cavans per hectare. At the current price of palay ₱17.50, the farmer would sell his harvest for ₱525, subtract his production cost of ₱200, and end up with a profit of ₱325. If he were a tenant he would only get some fraction of that amount.
>
> IR8 rice can cost any amount of money to produce, but a recommended optimum of ₱800 (not including land rental)

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[49] A discussion of these attributes in relation to fertilizer use is presented in Chapter IV.

> per hectare is advised. Using the minimum expected yield of 100 cavans per hectare, a farmer can sell his harvest for ₱1,750, subtract his maximum optimum cost of ₱800, and he still has a profit of ₱950 per hectare (or a part [of that amount] if he is a tenant). These estimates are very conservative since...experience [shows that] IR8 yields are usually much higher than 100 cavans per hectare.

Filipino farmers, like farmers anywhere, are rational. "An investment of ₱800 per hectare for a variety that they had never grown was frighteningly large for the average Filipino farmer whose entire annual income from rice farming had probably never equaled this amount" (USAID, 1967:12). Thus, it was recognized that the farmer would likely view an investment of ₱800 per hectare as too large a gamble. Not having had experience with the new technology (other than perhaps having observed other farmers using it), the farmer had little or no basis for judging what its profitability and reliability would be if used on his own farm. Thus, in comparison with the level of profitability and reliability (or, conversely, risk) associated with the technology traditionally used by the farmer, the new technology held out not only the possibility of greater returns, but also greater losses. The "Do-It-Yourself Rice Kit" provided the farmer with a means for minimizing the possible yield and financial losses and observing for himself the performance of the new technology, thereby reducing the risk associated with trying the new technology.

As a testament to the influence of the "Do-It-Yourself Rice Kit" on the adoption and diffusion of IR8 and associated inputs such as fertilizer, more than 22,000 kits were sold in the Philippines during a 1-year period (USAID, 1967:16). According to reports (USAID, 1967:16):

> ...the IR8 kits have accomplished every purpose for which they were created. Farmers have been so convinced of the performance of IR8 following the planting of a kit that in the season following the planting of a kit they have averaged an increase in area planted to IR8 of 10 times that of the original kit. Thus, the average farmer who planted a 2,000 square meter IR8 kit during one season, plants two hectares of IR8 the following season.

So successful was the "Do-It-Yourself Rice Kit" in stimulating adoption of the new technology that the National 4-H Club of the Philippines requested USAID's assistance in preparing

500 IR8 rice kits designed for 1,000 square meters (1/10 of a hectare). These kits sold for ₱40 and were paid for by the young farmers after they had harvested the rice crop. Five hundred additional rice kits for 1,000 square meters were planted by members of the Future Farmers of the Philippines. As demand for the kits increased, even the commercial agricultural supply companies began to market their own kits. The ESSO Fertilizer & Agricultural Company marketed 8,000 kits (each for 2,000 square meter plots) through more than 400 ESSO Agro-Service stores located all over the Philippines. Similarly, in 1967, the Atlas Fertilizer Company sold over 5,000 IR8 kits for 1,000 square meter plots through their countrywide chain of distributors.

Case Study 2: The Tetu Project

Ascroft, et al. (1973, and Roling (1974b, 1974c) report a field experiment that was carried out in Tetu Division of Central Province, Kenya, employing the experimental design presented in table 22. This "experimental design" is more appropriately termed a "quasi-experimental design," since the researchers "did not employ a control group of farmers who were similar to...experimental farmers...except for the experimental strategy" (Ascroft, et al., 1973:58). The design is limited in that the strongest type of conclusion that may be drawn is: "Y% of our experimental farmers, of whom only X% had ever used hybrid maize before the experiment, have now adopted in 1970" (Ascroft, et al., 1973:59). Thus, the possibility is left open that comparable farmers may have achieved the same adoption rate through normal extension and diffusion processes.

Operationally, the field experiment required that the researchers conduct a random sample (n = 354) of 12,000 registered farms in Tetu. On the basis of the number of innovations adopted by each farmer and the number of years each innovation had been used by each farmer, the researchers calculated an "innovativeness" or "progressiveness" score for each farmer. These scores were then collapsed into four categories: "most progressive," "upper middle," "lower middle," and "least progressive." The experimental manipulations consisted of the following:

1. Identification and Selection--An experimental group of farmers which was heavily weighted by a disproportionate number of "least progressive" farmers was identified and selected (see table 23).

Table 22. The Quasi-Experimental Design of the Tetu Project in Kenya (Ascroft, *et al*., 1973)

	Baseline	Farm Record Card	Experimental Strategy	After-Measure
Experimental group	No	Yes	Yes	Yes
All Tetu farmers	Yes	No	No	No

Table 23. Progressiveness of Farmers in the Experimental Group in the Tetu Project in Kenya (Adapted from Roling, 1974c:126)

Progressiveness	Participants	Baseline Sample
Least progressive	42	24
Lower middle	38	22
Upper middle	15	22
Most progressive	5	26
Total	100%	100%
Number in group	308	253[a]

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[a] Only areas of Tetu from which the participants were also drawn.

2. Recruitment of Farmers to the Project--"The selected farmers were asked to come to the house of the sub-chief who explained the project to them and asked them whether they wanted to participate. . . . The composition of [the experimental] group shows that it was possible to identify, select, and recruit 'forgotten' farmers. Only a few refused to come" (Roling, 1974c:125-126).

3. Transfer of Knowledge--The researchers, working with local officials and extension personnel, developed "a three-day course in hybrid maize growing at the Farmer Training Center (FTC). The course followed a carefully designed curriculum, in which motivation, group processes, visual aids, demonstrations, and participant activity had been built in" (Roling, 1974c:125).

4. The Provision of Credit and Supplies--"Participants in the [FTC] course obtained a voucher worth the inputs necessary to plant 1 acre of hybrid maize. This voucher could be exchanged for inputs necessary to plant 1 acre of hybrid maize.... No security was asked, although the possibility of prosecution of nonpayers was kept open. The main motivation for repayment was the automatic qualification for next year's loan" (Roling, 1974c:126).

5. The Provision of Followup--Extension workers who had visited the group taught at the training center continued to make themselves available to farmers throughout the experiment.

The results of the Tetu experiment were quite remarkable. Although farmers were selected in such a way that few grew hybrid maize before the experiment, nearly all the farmers (over 95%) adopted this innovation. Moreover, the majority of these farmers had been in the least progressive group. While the average yield of local maize had been about four bags per acre, the average for the experimental group was 11.4 bags per acre. The most important conclusion of the experiment, however, was:

> As a result of research on the diffusion of practices it has become accepted that diffusion only works by 'trickle down' from the top, i.e., from the most progressive downward. Yet in the experiment we found that for every farmer trained, another 3.7 farmers also adopted recommended practices. To the roughly 800 farmers trained [in various experimental groups], one must therefore add about 3,000 others who adopted

> spontaneously during the same planting season, as a result of contact with those who went to the course. It is clear that diffusion efforts can also occur if one aims at the bottom (Roling, 1974c:127).

Ascroft, *et al*. (1973:58-60) recognize a further limitation of their quasi-experimental design, namely, that the experimental manipulation "does not consist of one experimental action, but of many." Thus, for example, the researchers could not conclude "to what extent the high adoption rate was due to the course, to the loan, or to both in interaction." Numerous other factors including the innovation itself may also have causally influenced the outcome of the experiment. Ascroft, *et al*. (1973:59) conclude:

> The multitude of actions to which the achievements of the project can be attributed makes it very hard for us to specify which of the actions need to be replicated to achieve the results elsewhere. . . . To be able to attribute our results to specific actions, we should have employed different experimental and control groups.

Implications of Case Studies

These two case studies--the making available of a "Do-It-Yourself Rice Kit" and the involvement of least progressive farmers in a "Farmer Training Course"--illustrate the manipulation of one or more variables. The case study of the "Do-It-Yourself Rice Kit" provides an excellent illustration of the potential impact which a well-designed experimental "treatment" or "manipulation" can have in accelerating the rate of diffusion of an innovation. However, this program was neither based on nor served to test a field experiment methodology. Thus, the "Do-It-Yourself Rice Kit" experience does not permit ready generalization about the factors or variables which help to accelerate the rate of diffusion of an innovation.[50] On the other hand, the "Farmer

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[50] The "Do-It-Yourself Rice Kit" program in the Philippines is illustrative of many action programs which, although they may include a research component, are not carried out in a way that meets the conditions required of a field experiment. Another illustrative case is the Puebla Project in Mexico (CIMMYT, 1969, 1970, 1974; Myren, 1970, 1971; Sanchez, 1971; Diaz-Cisneros and Felstehausen, 1973; Diaz-Cisneros, 1974; Winkelmann, 1973, 1976a; Felstehausen, 1973; Peters, 1973; Tinnermeier, 1974; Biggs, 1974; Cummings, 1975; Gladwin, 1976, 1977; Byrnes, 1975; Whyte, 1975a; Jedlicka, 1977; Clawson and Hoy, 1979; Zandstra, *et al*., 1979; and Redclift, 1980).

Training Course" experience demonstrates that, without tight control over the exact variables being experimentally manipulated, one can only guess as to which factors really promote acceleration of an innovation's rate of diffusion (cmpr. Maji and Haque, 1979; Ray, et al., 1979; and Thomas, 1980).

Although these case studies permit only limited generalization of results, they do illustrate that the potential range of effective strategies for accelerating the rate of diffusion of an innovation is broader than that which is reflected by the "progressive farmer" strategy. Specifically, in terms of policy implications, the two case studies reviewed reinforce our earlier conclusions concerning the importance of increasing the availability of information to the smaller farmer (as in the "Farmer Training Course" experience in Kenya) and enhancing the trialability of an innovation (as in the "Do-It-Yourself Rice Kit" experience in the Philippines).

Finally, although a limited sample of two case studies only permits a correspondingly limited degree of generalization of results, the conclusions which may be drawn from these studies may be supplemented by the findings of a study contracted by the Agency for International Development (AID) to improve the design and implementation of projects to assist small farmers or, more specifically, farmers engaged in subsistence agriculture (Morss, et al., 1975c). This study examined 36 rural development projects in 11 African and Latin American countries. In the study, project success, the dependent variable, was measured in terms of an index combining scores on each of four distinct success components: (1) the project's income-to-cost ratio; (2) the acquisition of agricultural knowledge by small farmers; (3) the increase in self-help capabilities as a result of project activities; and (4) the chances of project benefits to small farmers becoming self-sustaining. A quantitative analysis of each project's success score in relation to a large number of possible success determinants revealed that "small farmer involvement in project decision-making and his resource commitment to the project account for nearly 50% of the differences in success scores of the projects" (Morss, et al., 1975c:2). In turn, "local action," the term used to refer to "small farmer involvement and resource commitment," was found to be significantly increased by the following: (1) an effective two-way communication between small farmers and project staff; (2) functioning local organizations controlled in large part by small farmers themselves; and (3) crop-specific (as distinct from general) extension service advice offered. Where these elements are present, farmers will in turn engage in "local action." That is, they will commit their resources and become involved in such activities as sharing responsibility for making decisions, testing new technology, and spreading new knowledge as semiprofessionals.

Specifically concerning the adoption of new technology, the evidence suggests that "the small farmer will take advantage of a good idea, when 'good idea' is defined to allow for constraints such as risks (i.e., chance for loss) and his assessment of the costs of taking such risks" (Morss, et al., 1975c:2). Interestingly, the study also found that literacy, land tenure and involvement in decision-making were positive influences on resource commitment; and the small farmers committed more resources, proportionately, than the larger, wealthier farmers. Additionally, "the size of the subsidy for adoption of new practices and the provision of social services in early project stages both appear...to have a negative effect on resource commitment" (Morss, et al., 1975c:2).

Finally, Morss, et al. (1975c:2-3) found that the most successful projects were those that began either (a) by learning about the local area prior to initiation or (b) by planning the project on the basis of a simple idea and developing knowledge about the area during the early stages of the project. They also found that census-like surveys, either for project design or as baseline data for use in measuring project success, are of little value. Lastly, they found that development projects which are heavily dependent on receiving funds of a sizable amount are less likely to do well in terms of local action, success, and self sufficiency. In terms of this last finding, major problems include (Morss, et al., 1975c:4-5):

* A time constraint caused both by a need on the part of the donor agencies to commit large sums of money and to show quick results;

* A knowledge constraint, originating from the belief of foreign and host country government staff members that small farmers have little to offer. . . .

* An assumption in project design that small farmers will change their behavior without an assessment of what changes (in terms of involvement and resource commitment) are required if the project is to achieve its objectives and of how they might be realized;

* The use of restrictive benefits measures such as cost-benefit ratios or repayment rates which narrow the focus of the project, instead of applying

> measures such as the increase in self-help capability, the acquisition of agricultural knowledge and progress towards making benefits independent of outside assistance.

The findings emerging in their study led Morss, et al. (1975c:2) to conclude that:

> The policy implications...are straight-forward: every effort should be made to foster small farmer involvement and resource commitments to projects in the early phases. The small farmers' involvement should complement (and ultimately replace) the work of the project's outside staff. The resource commitments (labor and cash) should complement (and ultimately render unnecessary) resources from outside sources.

Similar conclusions have also been reported by Galjart (1980), Buijs (1980), and Grijpstra (1980) in a series of studies on participatory development projects.

TREE ANALYSIS

Two types of tree analysis have been employed in research on the adoption and diffusion of innovations: (1) decision analysis (employing discrete data) and (2) configurational analysis (employing continuous data). As is illustrated by the figures accompanying discussion of these approaches, use of the term "tree" derives from the display of empirical results in the form of a branching tree with specific variables related to each branch.

Decision Analysis

The objective of decision analysis is to develop and test a discrete model of the factors determining individual farmer decisions to try or adopt an innovation. Several points are noted here to clarify a number of ways in which the type of decision analysis reviewed here is distinct from other analytical approaches to decision analysis.[51]

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[51] Anderson, et al. (1977) provide an extensive review of other approaches to decision analysis.

First, a decision analysis model is based on a hierarchial theory of choice which assumes that farmers view the world they experience in terms of discrete constraints which farmers take into account as a basis for making decisions. Decision analysis attempts to identify these constraints and build them into a model which predicts the decision making of individual farmers. Accordingly, the principal task which the researcher seeks to accomplish in using decision analysis is to identify those specific constraints. This task requires that the researcher determine what information is actually used by farmers in making decisions, as contrasted with information which although not used in decision making may nevertheless be given in response to interview questions. In using decision analysis, the researcher goes "back and forth between controlled interviewing (and acquiring information by direct observation) to produce a hypothesis about the specification of the decision criteria, and testing of the hypothesized criteria against the choice behavior of [a separate] sample of decisionmakers" (Gladwin, 1976).

Second, in contrast to conventional analytical models which specify a dependent variable as a function of a linear, additive combination of one or more explanatory or independent variables, the development of a decision tree model involves a hierarchial specification of those factors judged, on the basis of the researcher's observation, to be the constraints which are used by farmers in making decisions. An example of such a hierarchial specification is provided by the decision tree model presented in figure 4.

Third, while the parameters of conventional analytical models may be estimated with either micro (individual farm and/or farmer) or aggregate (e.g., district level) data (cmpr. Aklilu, 1976), a decision model may only be tested with data which describe the individual farmer's behavior.

Fourth, while conventional analytical models provide estimates of population parameters for each of the explanatory variables included in such models, a decision model predicts whether the farmer actually adopts an innovation or not and identifies the main factors which act as constraints to adoption. These factors are those decision criteria which correctly predict the largest percentages of nonadopters.

Gladwin (1976, 1977) used decision analysis to develop and test models of farmer decision making about increasing the quantities of fertilizer applied and adopting the various recommended practices in a village of Puebla, Mexico. One of these models, concerning the decision making about an innovation of planting closer together, is presented in figure 4.

Traditionally, Puebla farmers planted three or four seeds per hill (mata) of corn with hills 70 cm apart. This resulted in a seed population of 55,000/ha and a plant population of 36,630 plants/ha if 2/3 of the seeds germinate. Plan Puebla recommendations, for the village studied by Gladwin, called for approximately two or three seeds per hill with hills 40 cm apart, 64,000 seeds/ha, or 42,624 plants/ha if 2/3 of the seeds germinate. A farmer adopting this recommendation would increase his plant density by 6,000 plants/ha. While most farmers in the village in 1974 knew that the plan's recommendation was to plant hills closer (at 40 cm rather than at 70 cm), they were not aware that the recommendation also called for fewer seeds per hill. Farmers thought that the recommendation was to plant at 40 cm with three or four seeds/hill, 96,200 seeds/ha, or 64,165 plants/ha if 2/3 of the seeds germinate, an increase of 27,500 plants/ha. According to the plan's agronomists, given the soils and rainfall in the area, this is too high a plant population and adopting 40 cm at three or four seeds/hill will decrease rather than increase yields. Thus, the recommendation is to distribute the plants more evenly, with only two or three seeds/hill.

Turning to figure 4, the top node (or first constraint) in the decision to try or adopt the recommendation of an increase in plant population is a knowledge constraint which divides the sample of farmers into two subsets.

> One set of farmers decides about adopting 40 centimeters at 3,2,2 seeds per hill, the real recommendation. The other set of farmers decides about adopting "the wrong" recommendation, 40 centimeters at 3,4,3,4 seeds per hill. Both sets of farmers, in deciding between 40 and 70 centimeters, maximize gross returns (yields - cash costs) subject to the risk of losing plants and input costs constraints and a capital or credit constraint (Gladwin, 1976:884).

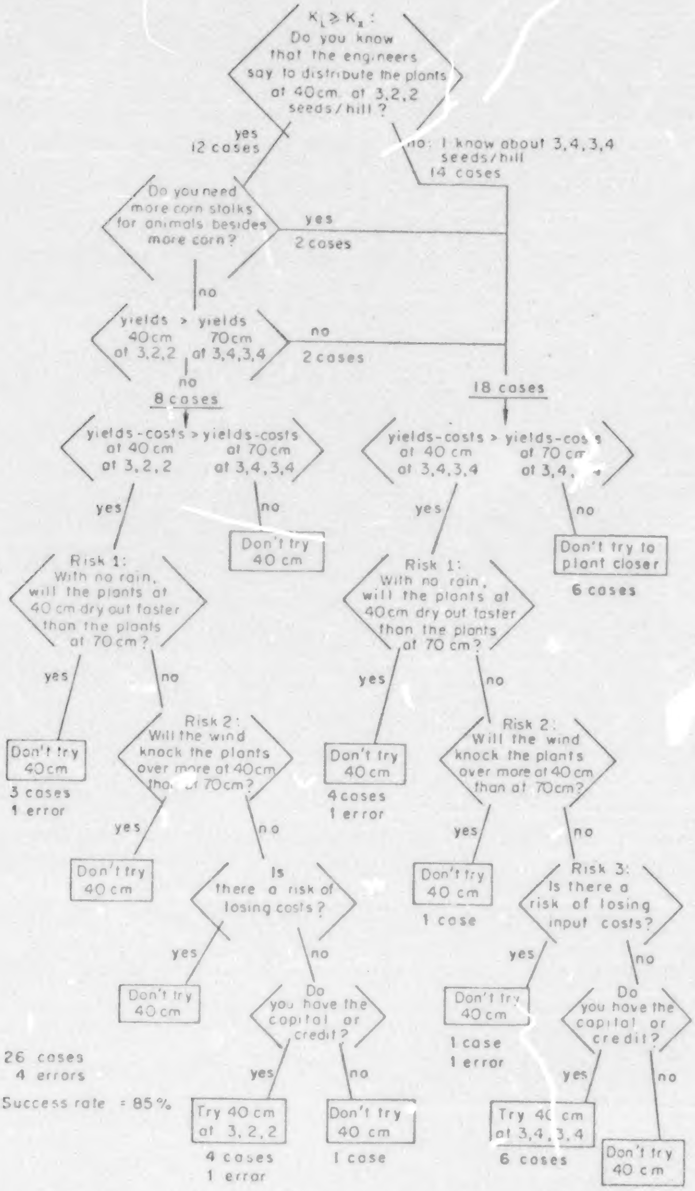
Data from decisions made by 26 farmers were used to test the model. The main factor limiting adoption of the recommendation was clearly lack of knowledge of the real recommendation, since 14 out of 26 farmers failed the knowledge constraint. Of the remaining 12 decisions, 3 farmers were ready to try (or did try) the recommendation. The model successfully predicted 85% of the farmers' decisions about plant population.

Figure 4 illustrates that the researcher employing decision analysis must identify what alternatives exist for the farmer and the criteria, rules, or reasons that provide a basis for predicting which alternatives will be chosen by the farmer. Thus, the researcher must not only identify the alternatives that farmers are choosing between, but also produce an hypothesis which specifies the criteria that provide the most error-free set of predictions of the choices that farmers will make. Then the researcher's model can be tested against the actual choices made in an independent sample of farmers. For an analysis involving a large number of farmers and/or types of decisions (e.g., decision to get credit, decision to change distance between plants, decision to change frequency of fertilizer application, decision to change rate of fertilizer application, etc.), a computer simulation program can be written that will test the model against the farmers' actual choices.

As an approach to research on adoption, decision analysis provides a means to develop and test a model of the process whereby an individual farmer reaches a decision to adopt or not adopt one or a combination of recommended innovations. Thus, for example, if it is hypothesized that "farmers do not adopt because they are risk-averse," then:

> ...this hypothesis would be tested by counting the number of farmers who thought that the recommendation was profitable and had the money or credit but thought that the recommendation was too risky, and so did not adopt. We only look at non-adopters because, in a tree model, an adopter has to pass all constraints: profitability, risk, and capital or credit availability. ...with the non-adopters, we can pick out the reason the farmers did not adopt (Gladwin, 1975b:57-58).

While decision analysis provides an innovative approach to the identification and estimation of the relative importance of factors acting as constraints to the adoption of innovations, the approach is not without its possible drawbacks. First, a decision model developed and tested at the village level may not be applicable to a larger area such as a region. The "generalizability" of the model will depend on the extent to which decision rules are shared across a region. If decision rules are not shared, the



$K_L \geq K_a$: Do you know that the engineers say to distribute the plants at 40 cm at 3,2,2 seeds/hill?
yes 12 cases
no: I know about 3,4,3,4 seeds/hill 14 cases
Do you need more corn stalks for animals besides more corn?
yes 2 cases
no
yields 40 cm at 3,2,2 > yields 70 cm at 3,4,3,4
no 2 cases
no 8 cases
18 cases
yields-costs at 40 cm at 3,2,2 > yields-costs at 70 cm at 3,4,3,4
yes
no
Don't try 40 cm
yields-costs at 40 cm at 3,4,3,4 > yields-costs at 70 cm at 3,4,3,4
yes
no
Don't try to plant closer
6 cases
Risk 1: With no rain, will the plants at 40 cm dry out faster than the plants at 70 cm?
yes
no
Don't try 40 cm
3 cases 1 error
Risk 2: Will the wind knock the plants over more at 40 cm than at 70 cm?
yes
no
Don't try 40 cm
Is there a risk of losing costs?
yes
no
Don't try 40 cm
Do you have the capital or credit?
yes
no
Try 40 cm at 3,2,2
4 cases 1 error
Don't try 40 cm
1 case
Risk 1: With no rain, will the plants at 40 cm dry out faster than the plants at 70 cm?
yes
no
Don't try 40 cm
4 cases 1 error
Risk 2: Will the wind knock the plants over more at 40 cm than at 70 cm?
yes
no
Don't try 40 cm
1 case
Risk 3: Is there a risk of losing input costs?
yes
no
Don't try 40 cm
1 case 1 error
Do you have the capital or credit?
yes
no
Try 40 cm at 3,4,3,4
6 cases
Don't try 40 cm
26 cases
4 errors
Success rate = 85%

Figure 4. A Decision Tree Model of Farmers' Decisions to Adopt the Plan Puebla Recommendation to Plant Closer Together (Gladwin, 1977: Figure 9)

researcher will need to develop a model which accounts for variation in decision rules in terms of additional explanatory factors (e.g., agro-climatic differences).

Second, decision analysis is time consuming in that it requires that the researcher find out the rules which farmers use in their decision making. Since the building of a decision model requires that the researcher get out in the field to gather and assess the "meaning" of the reports of the farmers, such a model cannot be based solely on a priori theory, the researcher's intuition, and/or reanalysis of secondary data.. This may be viewed as a drawback by those who believe that policy decisions can be made on the basis of conventional assumptions regarding the nature of farmer decision making (e.g., the assumption that the farmer is a profit-maximizing risk averter) and relatively quickly collected survey data which provides information on the farmer and his farming situation.

Third, since a discrete decision model does not produce predictions regarding the quantitative dimension (e.g., how much) of decision variables, there is a possibility that such models are only appropriate to or should be confined to the prediction of "whether to" decisions.

A final critique of decision analysis is that the factor identified as "the critical" limiting factor in a model may not remain critical under alternative orderings of the decision criteria included in the model. In this regard, Gladwin (1977) illustrates:

> If, when the order of a decision criteria on a path is changed, the main limiting factor also changes, then one should conclude that the selection of "the critical" limiting factor depends on its...position in the tree. Thus, if risk [rather than profitability] were the top node in [a hypothetical decision tree model], with profitability [rather than risk] second, with the result that the number of cases sent down each path were changed such that more non-adopters went down the "too risky" path than the "non-profitable" path, then one could conclude that the model cannot be used to pinpoint "the critical" limiting factor.

Whether this phenomenon indeed operates in a particular decision model can be empirically checked both in the process of building the model (e.g., while interviewing farmers) and in the process of collecting data. Enough data should be collected to permit the researcher to check not only whether the factor identified as the critical limiting factor in the original model remains so under an alternative model's orderings of the decision criteria but also whether a significant number of nonadopters have failed to adopt because of more than one constraint.

Configurational Analysis

The research approach herein referred to as configurational analysis consists of:

> ... dividing a sample of respondents into relatively homogeneous samples on the basis of several independent variables. Each sample or configuration is maximally homogeneous in regard to the independent variables, and this isolation of the variance serves to predict the dependent variable (Rogers and Ramos, 1965).

One type of configurational analysis is called the symmetrical method (Stuckert, 1958) in which each subsample is broken down through each independent variable. While the symmetrical method requires only a counter-sorter for analysis of the data, the method "entails somewhat arbitrary decisions as to the order in which independent variables are utilized" (Rogers and Ramos, 1965:12).

In contrast, the nonsymmetrical method (Sonquist and Morgan, 1964), also known as Automatic Interaction Detection (A.I.D.), is based completely on maximization of variance partitioning for decisions regarding (1) the order in which the independent variables will be utilized, (2) at what point to break a continuous variable, (3) which variables to exclude, etc. This approach, however, does require the assistance of a computer for the data analysis (Sonquist, et al., 1973). As described by Sonquist and Morgan (1964:2), A.I.D. focuses on

> ...a particular kind of data-analysis problem, characteristic of many social science research situations, in which the purpose of the analysis involves more than the reporting of descriptive statistics, but may not necessarily involve the exact

> testing of specific hypotheses. In this type of situation the problem is often one of determining which of the variables, for which data have been collected, are related to the phenomenon in question, under what conditions, and through what intervening processes, with appropriate controls for spuriousness.

Thus, A.I.D. is specifically designed for the types of data analysis where the interaction of the independent variables is expected to have an effect on the value of the dependent variables. Elaborating on this point, Sonquist and Morgan (1964:2) write:

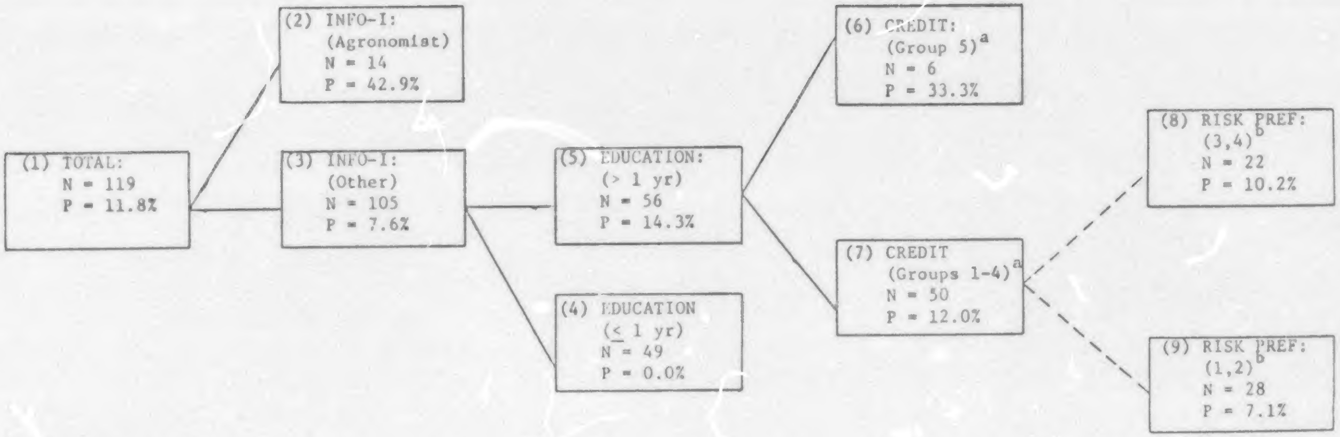
> The objective is to explain the variance of the dependent variable Y. Where the number of predictors is small, the problems of isolating the relationships between X_i and Y are manageable, but when the number of predictors is larger, which is typical of many survey data analysis problems, then an analysis of the joint effects of X_i on Y presents serious problems.

As compared with multiple correlation, A.I.D. provides certain advantages and disadvantages. First, preparing and interpreting a regression model with a large number of interaction possibilities (X_iX_j) becomes quickly burdensome. The A.I.D. program does not require the researcher to specify interaction terms in advance, yet it allows considerable flexibility for the interaction of variables and, in the course of computations, specifies these interactions. Second, the A.I.D. program can be used to analyze a dichotomous dependent variable. Third, the technique lends itself to a very comprehensible visual display of the program results in the form of a branching tree with specific variables related to each branch.

In terms of disadvantages, A.I.D. does require a sample size larger than 400 or 500. Operationally, A.I.D. divides and subdivides the sample on the basis of the variables which explain the greatest amount of total sums of square (maximizes the between sums of squares at each split). The smaller the sample size, the smaller the number of useful splits. Sonquist and Morgan set 25 as the minimum group size which can be considered legitimate. Second, the number of observations in each classification of an independent or predictor variable can quickly become too small to trust the significance of their mean value. Third, A.I.D. does not provide a beta coefficient (and accompanying statistics), that is, the technique does not relate numerical values of the independent variables to numerical values of the dependent variable. However, A.I.D. does provide an estimate of the value of the dependent variable (and accompanying standard deviation) for groups which include certain classifications from within the various independent variables (e.g., a mean adoption index of 57% for farmers with more than 1 year of education, per capita family incomes of over $200, and access to sufficient credit).

An example of an empirical application of configurational analysis by use of the A.I.D. program is provided by Peacock's (1972) study of the adoption of new agricultural practices by farmers in the Sao Francisco Rice Area of northeast Brazil. Of the 199 farmers identified as group 1 in figure 5, only 11.8% used fertilizer. The most important predictor of fertilizer use was the farmer's source of information (the agronomist) about the latest method being used; this variable explained 12.4% of the variance in the sample. Of the 14 farmers who had learned their latest method from the agronomist, 42.9% were using chemical fertilizer. However, of 105 farmers who had learned their latest method from other sources, only 7.6% were using fertilizer.

In the second "branching" of the "tree," the variable accounting for the next highest increment in the explained variance was education. As clearly seen in figure 5, fertilizer is used only by farmers with at least 1 year of education. In the third "branching," of the farmers who had completed more than 1 year of education, those (n = 6) who had obtained sufficient credit to meet their needs were more likely to use chemical fertilizer than the remaining farmers--33.3% as compared to 12%. These three variables (information, education, and credit combined to explain 18.7% of the variance in fertilizer use among Sao Francisco rice farmers. An alternative split of group 7 farmers is indicated by dashed lines, dividing the farmers into groups with "high" and "low" utility for additional income (as measured by a risk preference variable). This additional split, however, would explain only an additional 1.2% variance. Peacock (1977:252) concludes from these data that "factors related to the development of expectations about fertilizer are critically important to its adoption."


(1) TOTAL:
N = 119
P = 11.8%
(2) INFO-I:
(Agronomist)
N = 14
P = 42.9%
(3) INFO-I:
(Other)
N = 105
P = 7.6%
(4) EDUCATION
(≤ 1 yr)
N = 49
P = 0.0%
(5) EDUCATION:
(> 1 yr)
N = 56
P = 14.3%
(6) CREDIT:
(Group 5)a
N = 6
P = 33.3%
(7) CREDIT
(Groups 1-4)a
N = 50
P = 12.0%
(8) RISK PREF:
(3,4)b
N = 22
P = 10.2%
(9) RISK PREF:
(1,2)b
N = 28
P = 7.1%

KEY

N = Number of observations
P = Percentage using fertilizers

---

a. Credit
  1. Didn't use credit
  2. Obtained credit from non-commercial sources
  3. Obtained credit from credit cooperative
  4. Obtained credit from banks
  5. Didn't need additional credit (borrowed from one of the above)

b. Risk Preference (see Peacock, 1972:179-181 for discussion of the procedure used to measure this variable)
  1. Very low utility
  2. Low utility
  3. Medium utility
  4. High utility

Figure 5. A Configurational Analysis, Employing Automatic Interaction Detection, of Fertilizer Use by Sao Francisco Rice Farmers in Northeast Brazil (Peacock, 1972:248).

OTHER MULTIVARIATE ANALYSIS PROCEDURES

There are a variety of multivariate analysis procedures which can be used by the researcher in studying diffusion-related phenomena. Previous chapters of this monograph have already reviewed and illustrated the application of such procedures as multiple regression (e.g., logistic curve analysis) and multiple correlation (e.g., innovativeness analysis). None of the multivariate analysis procedures to be considered here presupposes any particular emphasis on any particular theoretical orientation or set of independent variables as is the case in the research approaches reviewed in this monograph's earlier chapters on geographical, economic, and sociological approaches to diffusion research. Three multivariate analysis procedures will be reviewed: path analysis, probit analysis, and factor analysis.[52]

Path Analysis[53]

Coward's (1969:86-94; Coward, et al., 1967) study of commercialization of Guatemalan agriculture provides an illustration of an empirical application of path analysis. To develop a measure of commercialization, the dependent variable, Coward combined each farmer's score on the extent to which the farmer markets the output from his farm and the extent to which he has adopted various recommended agricultural practices (e.g., fertilizer use).[54] Then, drawing upon theory, past research, and a preliminary regression analysis to determine which independent variables remained statistically significant in both backward and stepwise solution regression models, Coward specified what he hypothesized to be the "causal" ordering of the independent variables in relation to one another and, in turn, to the dependent variable. This step was accomplished by drawing a path diagram (figure 6) in which:

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[52] The reader is referred to Benito (1976) for a presentation of a multivariate analysis model, namely, a stochastic linear programming framework, which is not reviewed in any detail herein. Using such a framework, Benito developed a model of the peasant household which integrates many of the factors frequently suggested as explaining adoption of modern technologies by peasants. Observed low adoption rates and peasants' participation in the Puebla area of Mexico are explained by opportunity costs of time and uncertainty. Vail (1971) also employed a linear programming model to address the question:

> What "package" of agricultural innovations, consistent with farmers' knowledge, values and financial resources, has the greatest capacity to break current bottlenecks and maximize the growth of net farm income in the short run? Optimum farm practices and beneficial new material inputs in the form of seed varieties, fertilizer, and light equipment are identified under conditions of variable household resource endowments and uncertainty about seasonal rainfall distribution and future crop prices.

[53] Another approach to the causal modeling of the adoption of new technology in the developing countries is reported in Yetley (1968). See also Mason and Halter (1968) and Yetley and Deaton (1979).

1. Each hypothesized causal relationship is shown by a unidirectional arrow extending from a determining variable to a dependent variable.

2. Each noncausal (i.e., correlational) relationship is shown by a two-headed or bidirectional curved arrow (not shown in figure 6). The value of the correlation coefficient between any two exogenous variables may be entered alongside its corresponding two-headed curved arrow.

3. Each residual variable is related to its respective dependent variable by a unidirectional arrow. Each residual variable R_i remains unmeasured.

4. The numerical value for each unidirectional arrow will be represented by an estimated path coefficient.

Coward represents the path diagram with a set of recursive equations. "For each of the endogenous variables in the path diagram a regression equation [was] written in which the independent variables are those variables hypothesized in the path diagram to be directly related to the endogenous variable being considered" (Coward, 1969:146, 148). For example, the regression equation for credit orientation score (X_8)is:

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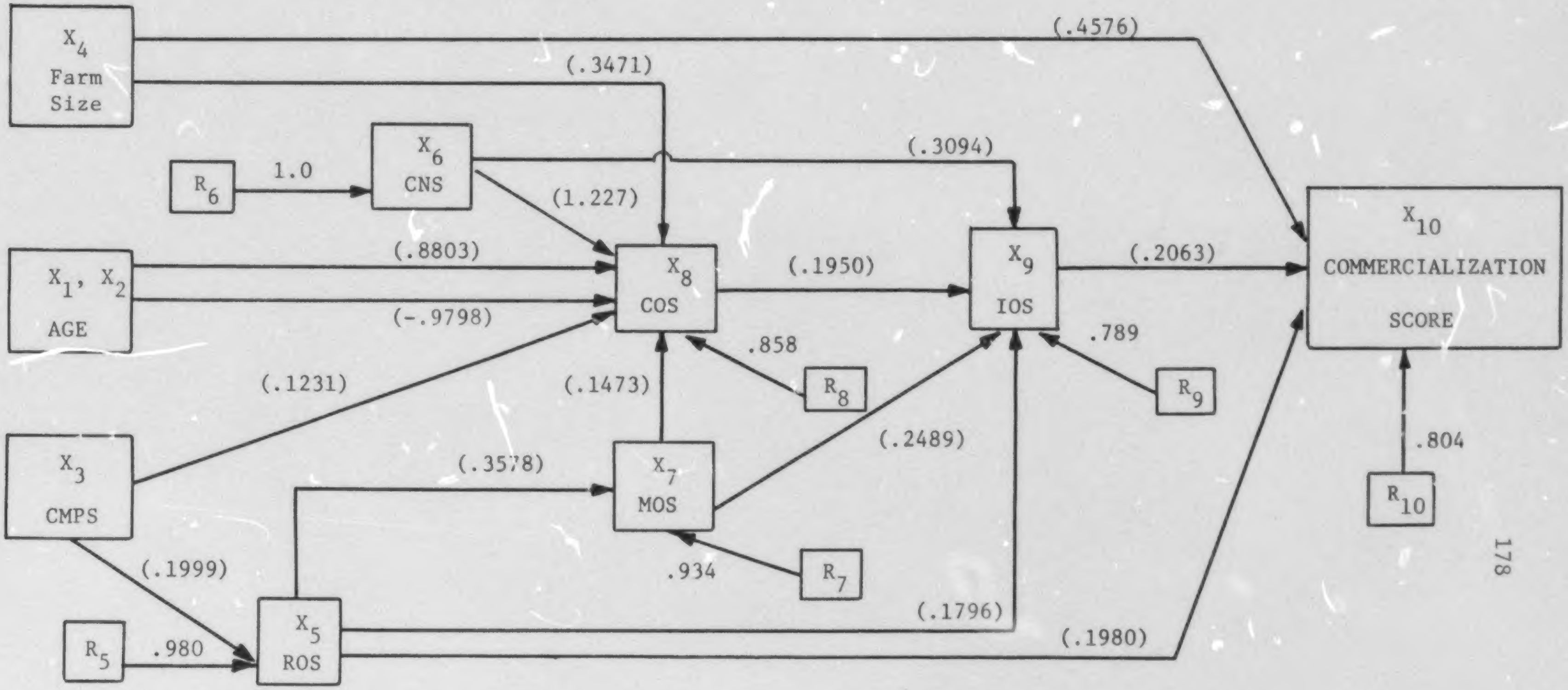
[54] In the sample of Guatemalan farmers (Coward, 1969:89), 22% of the farmers were scored as operating at the subsistence level (little or no marketing), 46% as secondary marketers (selling a large portion of their secondary crop only), 17% as major marketers (selling a large portion of their major crop only), and 15% as commercial marketers (selling a large portion of both their major and secondary crops).

*



X4 Farm Size
(.4576)
(.3471)
R6
1.0
X6 CNS
(.3094)
(1.227)
X1, X2 AGE
(.8803)
(-.9798)
X8 COS
(.1950)
X9 IOS
(.2063)
X10 COMMERCIALIZATION SCORE
.858
R8
.789
R9
(.1231)
(.1473)
(.2489)
.804
X3 CMPS
(.3578)
X7 MOS
R10
(.1999)
.934
R7
(.1796)
R5
.980
X5 ROS
(.1980)

KEY

X_1 = age (linear)

X_2 = age (quadratic)

X_3 = cosmopoliteness score (CMPS)

X_5 = risk orientation score (ROS)

X_6 = control-over-nature score (CNS)

X_7 = market orientation score (MOS)

X_8 = credit orientation score (COS)

X_9 = information orientation score (IOS)

*Bidirectional arrows between any pairwise combination of exogenous variables are not included in this path diagram.

Figure 6. A Path Diagram: A Graphic Representation of a Path Model (Adapted from Coward, 1969:176)

$$X_8 = b_{81.234567}X_1 + b_{82.134567}X_2 + b_{83.124567}X_3 + b_{84.123567}X_4 + b_{85.123467}X_5 + b_{86.123457}X_6 + b_{87.123456}X_7$$

For the path diagram in figure 6, six regression equations would be written.

To determine each path coefficient's value, the partial regression coefficients (b_i) in each of the six regression equations were calculated using ordinary least squares regression. A t-test was applied to each coefficient b_i and each b_i not statistically significant was eliminated from the model. Repeating this procedure until each regression equation contained only statistically significant coefficients, Coward (1969:149) eliminated all nonsignificant coefficients, leaving the following set of equations:

$$X_5 = b_{53}X_3 + e_5$$

$$X_6 = e_6$$

$$X_7 = b_{75}X_5 + e_7$$

$$X_8 = b_{81.23467}X_1 + b_{82.13467}X_2 + b_{83.12467}X_3 + b_{84.12367}X_4 + b_{86.12347}X_6 + b_{87.12346}X_7 + e_8$$

$$X_9 = b_{95.678}X_5 + b_{96.578}X_6 + b_{97.568}X_7 + b_{98.567}X_8 + c_9$$

$$X_{10} = b_{10,4.59}X_4 + b_{10,5.49}X_5 + b_{10,9.45}X_9 + e_{10}$$

This modified set of equations is represented by the path diagram in figure 6. Since a path coefficient (p_{ij}) is identical with the standardized partial regression coefficient ($b_{ij}*$), by standardizing the raw partial regression coefficients (b_{ij}), one obtains an estimate of the path coefficients (Land, 1968). These coefficients ($p_{ij} = b_{ij}*$) have been added to the path diagram in figure 6, for example, p_{97} = .2489.[55]

---

55. Since none of the regression equations in the modified set approached complete determination of the respective dependent variables, the introduction of residual path coefficients was required. A residual path coefficient is interpreted as the proportion of the variance of an endogenous variable that is caused by all variables outside the model being considered and is estimated by taking the square root of $1-R^2$. The calculated residual path coefficients for each of the regression coefficients has been added to the path diagram in figure 5, for example, R_5 for X_5 = .98.

The path model in figure 6 is to be interpreted as "one statistically satisfactory set of interrelationships based on the causal ordering of variables assumed a priori and on the empirical analysis of the study data" (Coward, 1969:152). Specifically, the path coefficients are an "interpretation of the direct relationships among variables and the relative strength of these relationships" (Coward, 1969:153). By examining the path diagram in figure 6 the reader will note that farm size (X_4) has the strongest direct effect on the commercialization score (X_{10}), followed by information orientation score (X_9) and risk orientation score (X_5).[56]

While the objective of path analysis is to build and test a path model of the variables which are "causally" effective in "producing" change in the specified dependent variable (e.g., adoption, rate of diffusion, quantity of fertilizer used, etc.), the achievement of this objective requires that the researcher specify the ordering of the variables that are to be included in the model. The difficulties encountered by the researcher in this respect are summarized by Coward (1969:144-145):

> The lack of theoretical guidelines and the absence of past empirical work makes establishing the causal ordering a difficult task. Most theoretical discussions deal only with an inventory of concepts that are related to some common concept. There is little axiomatic theory relating concepts in a cumulative manner. Likewise, most empirical work has dealt with only two variable relationships, or the partial relationships between an independent and dependent variable, when other independent variables are considered. The result is that the preliminary application of path analysis to a substantive area...must proceed partially based on the

---

[56] An additional step in path analysis is the calculation of the total indirect effect of each variable on the dependent variable (e.g., commercialization). Following Land's (1968) procedure for calculating the total indirect effect for each variable, as well as each variable's partial indirect effect along each indirect path, Coward (1969:155) finds the greatest total indirect effects are credit orientation score (X_8), followed by market orientation score (X_7), and control-over-nature score (X_3). Of the three variables (X_4, X_9, X_5) with the strongest direct effect on commercialization score (X_{10}), risk orientation score (X_5) has the largest indirect effect.

> best judgment of the researcher. . . . ...to proceed the researcher must be willing to assume a causal ordering of the variables a priori with respect to the data being analyzed.

It is important to emphasize that in using path analysis, the researcher may make any or all of three erroneous assumptions: (1) that the causally influential variables have been included in the model; (2) that the variables included in the model are validly and reliably measured; and (3) that the variables included in the model have been properly ordered in a causal sense. On the other hand, if the researcher does not violate any of these assumptions, then the estimated path coefficients may be used as weights which, when applied to standardized observed values of the independent variables, provide estimates of predicted values for the dependent variable. In view of such considerations, extreme caution must be exercised in drawing substantive conclusions and policy or program implications from a path model. The path coefficients which are estimated only provide information on the relative weight or importance of those variables which the researcher initially decides to put in the model and which "survive" as statistically significant. Once these path coefficients are estimated, the technique of path analysis provides no means (e.g., such as is the case with the use of R^2 in evaluating alternative regression models) of comparing the path model with any other path model that might have been conceptualized and estimated by the researcher.

Probit Analysis

Studying adoption of fertilizer use among farmers in western Nigeria, Falusi (1973, 1974:3) used multivariate probit analysis "to identify the factors...likely to influence the adoption of fertilizer use among small-holders and the possible effects of different policy instruments designed to stimulate or encourage adoption." In Falusi's (1974:5) probit model,

> ...the probability of observing a response (a farmer who used fertilizer) is defined in terms of a single unobserved index or stimulus, and the standard cumulative normal distribution...is used to transform the index to the probability value. . . . Index I may take on any value...but the transformation insures that all the corresponding probability values lie between 0

> and 1. The stimulus I cannot be observed but is defined to be a linear combination of the observable variables . . . as follows:
>
> $$I_t = B_0 + B_1X_{1t} + B_2X_{2t} + \ldots + B_nX_{nt} \ldots$$

To estimate the model's unknown parameters (B_n), Falusi used a maximum likelihood estimation technique. The resultant coefficients were used to estimate change (ΔI) in the stimulus level I, assuming either a 10% increase from the mean level of each quantitative variable or a change from 0 to 1 for each qualitative variable. On the basis of the magnitude of the coefficients and the predicted changes in stimulus level (ΔI), presented in table 24, Falusi (1974:13) concludes that the important variables influencing fertilizer adoption are membership in a Cooperative or Farmers' Association, regular attendance at farmers' meetings, availability of credit, and frequent extension contact.

To illustrate the policy implications of the probit model, Falusi calculated the index I for each farmer under the assumption of either a quantitative (e.g., 10% increase) or qualitative (from 0 to 1) change in one of the independent variables (e.g., from $X_5 = 0$ to $X_5 = 1$, representing liberal credit facilities). He then used the standard cumulative normal distribution to transform the new index I for each farmer to a predicted probability of using fertilizer and summed the resultant probabilities across all farmers. As indicated in table 25, the percentage of farmers who were adopters rose from an observed 48.3% (129 out of 265) to a predicted 51.3% (136 out of 265), an increase of 6.5%. This process was repeated for each of the other qualitative variables and the resultant figures are presented in table 25.

As the sum of the estimated probabilities corresponds to the estimated number of farmers using fertilizer, the difference between two estimated numbers represents the differential impact of the two policy alternatives in question. Thus, for example, given the state government's policy to promote and actively encourage Farmers' Cooperatives, Falusi (1974:14) asks what would be the effect on the adoption of fertilizer use if all farmers in the sample were members of Farmers' Cooperatives:

Table 24. Probit Model Regression Coefficients for the Determinants of Adoption of Fertilizer Use by Local Farmers in the Western State of Nigeria, 1971 (Adapted from Falusi, 1974)

Explanatory Variables[a]	Unit of Measurement	Coefficient	Mean Labor	Change (↑) in Stimulus Level
X01 Farm size	ha	0.0135	5.0	.0067
X02 Regular labor force	m.e.[b]	-0.0525	2.85[c]	-.0150
X05 Availability of credit	-	0.3136	-	.314
X06 Cooperative membership	-	0.6122	-	.612
X08 Frequent attendance at farmers' meetings	-	0.4690	-	.470
X09 Infrequent attendance at farmers' meetings	-	0.950	-	.100
X10 Frequent extension contact	-	0.3010	-	.301
X11 Infrequent extension contact	-	0.1230	-	.123
X12 Price of rice	d/kg[d]	0.1274	11.6	.147
X13 Price of maize	d/kg	0.2341	3.05	.071
X14 Price of yam	d/kg	0.1548	2.8	.043
X15 Price of cassava	d/kg	0.0651	1.0	.0065

---

a. Dependent Variable is "whether farmer uses fertilizer" (yes = 129; no = 136).

b. m.e. = the number of man-equivalents of people who work full-time or regularly on the farm.

c. Total labor.

d. d = pence.

Table 25. The Effects of Different Policy Alternatives on Adoption of Fertilizer Use in the Western State of Nigeria, 1971 (Falusi, 1974:14)

Policy Set	(1) Sum of Probability $\Sigma_{t=1}^{T} P_t$	(2) Estimated Number of Adopters	(3) Percentage Change from Original Situation (1)	(4) Percentage Change Farmers Adopting
No Change	128.83	129	-	48.3
Liberal Credit Facilities (X_5 = 1)	135.71	136	6.25	51.3
Promotion and Encouragement of Farmers' Cooperatives (X_6 = 1)	156.44	156	21.88	58.9
Improved Social Participation (X_7 = 1)	139.05	139	8.60	52.5
Expanded Extension Education Scheme (X_9 = 1)	147.53	148	15.62	55.8
Combination of Policies 2, 3, 4, and 5	189.96	190	48.44	71.7

> This could be estimated by making a comparison between the sum of predicted probabilities using the observed values for the Cooperative membership variable (X_6) and all other variables, and the sum after specifying the same variable as 1 for all observations; leaving all other variables the same. The result shows an almost 22% increase in adoption from the original estimated number of adopters.

From the results reported in tables 24 and 25, Falusi (1974:15) concludes:

> that the stimulus index of fertilizer adoption is influenced more by institutional and educational considerations than by economic factors. The stimulus level associated with variables such as frequency of extension contact, attendance at farmers' meetings, membership of Cooperative Societies and/or Farmers' Associations and credit/capital supply are much larger than those associated with such factors...as farm size, labor input, and crop prices. Profitability undoubtedly is a necessary but clearly not a sufficient condition for fertilizer adoption.

Accordingly, argues Falusi (1974:15), the usefulness of multivariate probit analysis for studying adoption of fertilizer use:

> ...lies in not only identifying the variables that influence a dependent variable (in this case, stimulus (I) associated with fertilizer adoption) but also in estimating (quantitatively) the effects of different policy alternatives on fertilizer adoption. With a knowledge of costs, one might then decide which policy alternative is likely to achieve the greatest impact per unit of expenditure.

Factor Analysis[57]

Aklilu (1976) used factor analysis in a study of adoption behavior on the part of farmers in the Ethiopian Minimum Package Programme Areas (MPPAs). The study's dependent variables were (1) index of fertilizer use, measured by the amount of fertilizer used by the farmer, divided by "the amount recommended per hectare times the area cultivated" and (2) years of fertilizer use, measured by the number of years which the farmer had been using fertilizer. To assess the relative importance of the explanatory variables hypothesized as accounting for variation in the dependent variables, Aklilu surveyed farmers in two MPPAs which had been identified from secondary data as having the highest and lowest percentages of fertilized area, Jimma and Bako, respectively.

In Jimma (table 26), the MPPA with the highest percentage of fertilized area, Aklilu found that 92% of the variance in the index of fertilizer use was explained by factor 1 (F1) which included the following variables: man-to-land ratio, ox-to-land ratio, borrowings, consumption units in family, and tenancy. Aklilu points out that the index of fertilizer use (or level of adoption) is influenced by two different but complementary forces which are represented by the variables in F1--profitability of fertilizer use and economic pressure to adopt fertilizer use.

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[57] Although factor analysis may be used for testing hypotheses, this analytical technique has primarily been used in exploratory data analyses. Factor analysis reduces a set of hypothesized explanatory variables into a smaller number of independent groups or clusters called factors in terms of which the whole set of variables can be understood. In carrying out a factor analysis, a computer groups within the same factor those variables that are intercorrelated with one another, with variables being assigned to one or another group in such a way as to maximize the percentage of variance explained in the data set by each successive factor. For the researcher using factor analysis, the problem is to interpret the factors into which the variables have been grouped. This problem becomes particularly complex when diverse variables indicating unrelated phenomena cluster within the same factor. Accordingly, one means of evaluating a factor analysis is by the extent to which one is able to unambiguously interpret the identified factors. The reader desiring more detailed information about factor analysis may consult such references as Eysenck (1952), Scott (1966), and Harman (1967).

Table 26. Percentage of Variance Explained by Seven Factors in a Factor Analysis of the Diffusion of Fertilizer Use in Jimma MPPA of Ethiopia (Aklilu, 1976:128)

Characteristics Explained	Factors							h_i^2 [a]
	F_1	F_2	F_3	F_4	F_5	F_6	F_7	
Index of Fertilizer Use	92	2.04	.30	.21	.03	.02	.02	94.62
Time of Initial Fertilizer Use	.14	36.12	2.62	.74	4.58	2.82	.07	47.09
All Characteristics	39.10	9.40	6.80	5.50	10.50	24.0	4.70	100.00

---

a. In factor analysis, h_i^2 is the symbol conventionally used to refer to the percentage of variance explained in the total data set.

First, higher availability of labor and capital (represented by the man-to-land and ox-to-land ratios) can contribute little by themselves to increase output unless the farmer resorts to more extensive farming by bringing new land into cultivation. However, since land is a constraint, demonstrated by the fact that Fl is also highly correlated with tenancy, the high man-to-land ratio and ox-to-land ratios are highly complementary to using fertilizer, a land augmenting innovation, in more intensive farming. In this regard, Aklilu (1976:133) writes:

> The demand for labor and ox power increases with the use of fertilizers. Fertilized seed requires better seed-bed preparation. Since fertilizer also nourishes and increases the weed population, more frequent and intensive weeding is needed. Finally, to facilitate oxen-weeding, rowplanting, which requires more man hours, is generally recommended along with the adoption of fertilizers. Consequently, fertilizer, by optimizing the use of the existing relatively abundant resources, increases their respective marginal products significantly.

Thus, for farmers who have relatively plentiful labor, capital (oxen), and cash outlay (borrowings) but lack cultivable land (those farmers under tenancy), fertilizer use is a profitable innovation. This interpretation is clearly supported by the data in table 27 in which the mean index of fertilizer use of the farmers scoring high on Fl (top 20%) is 116%, which exceeds the level of the extension agent's recommendation by 16%. On the other hand, farmers scoring low in Fl (bottom 20%) have a mean index of fertilizer use of 27% (or approximately 25% of the recommended rate). And, as the reader may also observe in table 27, the mean resources of these two groups of farmers are significantly different.

The second force operating within Fl is that of an economic pressure to adopt fertilizer use. This is reflected by the clustering within Fl of both tenancy and consumption units in the family. The interrelationship of tenancy with economic and other social variables such as consumption units in the family is illustrated by the data in table 28. Aklilu found not only significant differences among the nontenants (those who own their land), part owners (tenants who own part of the land they cultivate but rent in the rest), and pure tenants in the average size of cultivated holding (2.95, 1.80, and 1.45 hectares,

Table 27. Average Characteristics of Farmers in Jimma MPPA of Ethiopia Who Scored High and Low on Factor 1: "Pressure to Adopt a Profitable Innovation" (Aklilu, 1976:134)

Characteristics	High Score N=52	Low Score N=56
Index of Fertilizer Use	116.00[a]	26.90[a]
Time of Fertilizer Use	.82[b]	2.20[b]
Cultivated Holding	.95[b]	4.64[b]
Owned Holding	3.74[b]	7.84[a]
Man-to-Land Ratio	14.64[a]	.85[a]
Ox-to-Land Ratio	2.60[a]	.44[a]
Borrowings	43.30[b]	4.80[b]
Tenancy	90.30[b]	15.80[b]
Consumption Units	17.87	1.15
Distance to Agent's Office	1.13[b]	2.05[b]
Age	41.80[b]	48.80[b]

a. Mean significantly different from each other at .05 level.
b. Mean significantly different from each other at .01 level.

Table 28. Average Characteristics of Farmers Classified by Tenure in Jimma MPPA, 1974 (Aklilu, 1976:137)

Characteristics	Pure Owner Owner-Renter N=171	Part Owner N=85	Pure Tenant N=24
Index of Fertilizer Use	45.30[b]	95.90[b]	16.40
Year of Fertilizer Use	1.725	1.600	.667
Tenancy	0	76.2	117
Cultivated Holding	2.95[b]	1.80[b]	1.45
Man-to-Land Ratio	2.36[a]	9.19[a]	2.88
Ox-to-Land Ratio	.877	1.808	.749
Borrowings	18.25	25.02	9.17
Consumption Units in the Family	3.23[a]	10.63[a]	4.55
External Extension Contact	4.98[b]	3.78[b]	2.83
Fertilizer Motivation Index	5.46[b]	5.76[b]	5.38
Media Exposure Index	1.44[a]	1.40[a]	.833
Government Exposure Index	7.27[a]	7.02[a]	5.54

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a. Mean significantly different from each other at .05 level.
b. Mean significantly different from each other at .01 level.

respectively) but also significant differences in the index of fertilizer use (45.30, 95.90, and 16.40, respectively). Variation in the index of fertilizer use is explained by a combination of several factors. First, in comparison with the nontenants (those who own their land), part owners have significantly more land and oxen and greater borrowings per cultivated hectare; they also have larger families (more consumption units) that need food and therefore have a higher fertilizer motivation index. Given that fertilizer use is profitable, especially in enhancing the marginal productivity of inputs such as land, labor, and oxen, and in increasing the amount of food which can be grown per hectare to meet family needs, the effect of this particular combination of variables is to create an economic pressure for the part owner tenants to adopt fertilizer use.

This interpretation is further reinforced by examining the pure tenants in terms of these same variables. This group has the lowest index of fertilizer use, "precisely because it lacks the complementary factors that are necessary to make fertilizer a profitable innovation" (Aklilu, 1976:136). Specifically, as compared with the part owners, the pure tenants have a lower man-to-land ratio, a lower ox-to-land ratio, lower credit availability (reflected by lower borrowings), lower consumption units in the family, and lower fertilizer motivation index, all of which combine to reduce the economic pressure and incentive to adopt fertilizer use.

The conclusion which may be drawn from these data is that economic pressure, such as tenancy (which implies a land constraint) or higher consumption units in the family (which implies more people immediately dependent on the farmer for food), may provide incentive to adopt but is not sufficient to determine whether an innovation will be adopted or not. Adoption will also depend on the complementarity of the innovation with available resources, whether the farmer can obtain credit for purchasing fertilizer and other inputs, and the extent to which the innovation under consideration is effective in relaxing constraints on production.

While F1 is important in explaining variation in the index of fertilizer use, this factor does not account for even 1% of the variation in the time of initial fertilizer use. Aklilu (1976:138) interprets this finding as meaning that the initial time of adoption and the level of adoption are different phenomena and that variation in these phenomena are explained by different factors. For example, although part owners have a higher index of fertilizer use as compared with nontenants (table 27), the part owners lagged behind the nontenants in terms of the average years of fertilizer use. Also, the pure tenants were the only group not initiating use of fertilizer in the first year (1971) that this input was available. Finally, while the part owners had the smallest percentage of farmers using fertilizer in 1971, this group led all others by 1974, with 86% of the group having become adopters by that time. In contrast, 54% of the pure tenants were still nonadopters in 1974.

In view of such considerations, Aklilu focused on the next factor (F2) which, while accounting for only 2% of the variation in the index of fertilizer use, explained 36% of the variation in the time of initial fertilizer use. The variables most highly correlated with F2 are external extension contact, local extension contact, fertilizer motivation index, and management knowledge index. The fertilizer motivation index is based on the farmer's attitude toward the effect of fertilizer on yield as well as the number of farmers he knows that use fertilizer. The management knowledge index is based on the farmer's knowledge of recommended fertilizer application rates, the price of fertilizer, and the effect of rowplanting on yield. As seen in table 29, farmers with higher extension contact were earlier in initiating use of fertilizer than farmers with lower or no extension contact. These same farmers also used more fertilizer per hectare although, as already seen, other factors (e.g., number of family members per hectare, access to complementary inputs, etc.) are also important in determining the level of adoption of fertilizer use.

Also, in relation to the year of initial fertilizer use, the farmers who rented all of their land lagged behind those who owned part of their land who, in turn, lagged behind those who owned all of their land. Table 28 shows that farmers with smaller owned and cultivated holdings, lower social status, and lower social participation were also those who had less extension contact. Moreover, although only indirectly reflected by the average fertilizer motivation index, the cumulative percentage of adopters in each year was smaller in the groups with less extension contact than in the groups with more extension contact (Aklilu, 1976:142). Consequently, farmers with less extension contact also knew fewer farmers who were using fertilizer and, relatedly, had less opportunity to see that fertilizer has a favorable effect on yield. Finally, the farmers with less extension contact and lower media exposure had a lower management knowledge index (less knowledge about price, application rate, and effect of fertilizer) and were later in adopting fertilizer use. On the other hand, the cumulative percentage of adopters in the "no extension" and "low extension" groups had reached 57% and 66%,

Table 29. Average Characteristics of Farmers Classified by Degree of Extension Contact in Jimma MPPA, 1974 (Aklilu, 1976:143)

Characteristics	High Extension Contact N=140	Low Extension Contact N=124	No Extension Contact N=16
Index of Fertilizer Use	75.80	37.80	38.00
Year of Fertilizer Use	1.964	1.282	.813
Owned Holding	7.939	3.969	2.592
Cultivated Holding	3.067	1.946	1.366
Social Status	3.200	2.548	2.063
Management Knowledge Index	8.021	7.121	3.625
Fertilizer Motivation Index	5.98	5.23	4.13
Media Exposure Index	1.564	1.234	.875
Government Exposure Index	7.800	6.234	6.813
Distribution to Agent's Office	1.38	1.43	1.20
Social Participation	1.864	1.161	.938

respectively, by 1974, which suggests that farmers with little or no extension contact were still able to obtain information about fertilizer use from previous adopters and this facilitated their adoption.

As may be seen in table 26, the remaining five factors had a negligible effect on either the level or the time of initial fertilizer use. Factor 3 (walking distance to extension agent's office and walking distance to the nearest all-weather road) was more related to the time of initial fertilizer use than to the index of fertilizer use. This suggests that distance had some influence on the time of initial fertilizer use. In this regard, Aklilu (1976:144) emphasizes that each MPPA is set up "in such a way that farmers, as long as they reside within the confines of the MPPA, will have an almost equal chance of being reached by the extension agents." Despite this consideration, table 29 indicates that all farmers did not have "an almost equal chance" of extension contact; those farmers with higher social status and larger farm size had more extension contact.

While Factor 4 (level of education and media exposure) and Factor 7 (age) were positively correlated with both of the dependent variables, each of these factors accounts for only a small percentage of the variation in either of the dependent variables. However, Factor 5 (social status and social participation) accounts for some of the variations in the time of initial fertilizer use. Aklilu (1976:147) interprets this factor as follows:

> Farmers with higher social status and higher social participation are often very influential at the village level. They are the people who are considered as the "opinion leaders".... Such farmers are almost always the first recipients of [information] regarding innovations since change agents attempt to reach their target population through them. Consequently, they are encouraged, if not pressured, by change agents to...implement the innovation as soon as possible so that the rest of the farmers...will adopt the innovation through the process of first imitation and later realization of the actual advantages of the change.

The effects of significant differences in access to information, as a function of social status, on the year of initial fertilizer use may be inferred from table 30. Differences between farmers in

Table 30. Extent of Difference in Information Availabilities Between Farmers Classified by Social Status in Jimma MPPA, 1974 (Aklilu, 1976:149)

Characteristics	Higher Social Status N=48	Lower Social Status N=232
Index of Fertilizer Use	50.00	58.00
Year of Fertilizer Use	2.17[b]	1.48[b]
External Extension Contact	5.65[b]	4.18[b]
Local Extension Contact	2.42	2.45
Media Exposure	2.54[b]	1.14[b]
Government Exposure	7.91[a]	6.17[a]

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a. Mean significantly different at .05 level.
b. Mean significantly different at .01 level.

social status and/or how extension workers respond to such differences explain in part why farmers' contacts with extension workers differ.

Finally, Factor 6 (owned holdings, cultivated holdings, and value of livestock owned), an "Economic Ability" factor, was not important in explaining variation in either of the dependent variables. According to Aklilu (1976:150), the availability of credit in the MPPAs was, at least in theory, not a constraint as "the MPP's credit system is such that most farmers irrespective of size, tenure, and asset position will be able to utilize it." However, while there were no major differences among farm size groups in the time of initial fertilizer use, smaller farmers (cultivating less then 4 hectares) tended to lag at least 1 year behind larger farmers in the time of initial fertilizer use. Interestingly, Aklilu (1976:153-154) found that the rates of diffusion of fertilizer use were strikingly similar across groups of differing farm size.

On the other hand, the level of fertilizer use was found to vary inversely with the size of cultivated holding (table 31). Tenancy is more prevalent among smaller farms and nonexistent in the farm size groups above 6 hectares. Smaller farmers tend to have higher man-to-land ratios, ox-to-land ratios, and levels of fertilizer use than do larger farmers. Other studies (cmpr. Schluter, 1971; Schluter and Mellor, 1972; Greene, 1971, 1973) have similarly found such a process to operate, with small farmers lagging behind larger farmers in terms of initially adopting an innovation but reaching a higher level of use once they start using the innovation.

In a similar factor analysis of farmers in Bako, the Minimum Package Program Area (MPPA) with the lowest percentage of fertilized area after 4 years, Aklilu found that "access to information" was the most significant factor in accounting not only for the time of initial fertilizer use but also the level of fertilizer use. As the reader will recall from the earlier discussion of Aklilu's logistic curve analysis (Chapter III) of the growth in the percentage of area fertilized in the group which included Bako, the innovation of fertilizer use was not very profitable and the variations in yield were quite high. In spite of these negative characteristics, the clustering of information-related variables in the "access to information" factor accounted not only for the time of initial fertilizer use but also the level of fertilizer use. This suggests:

Table 31. Average Characteristics of Farmers Classified by Area Cultivated in Jimma MPPA, 1974 (Aklilu, 1976:154)

Farm Size in Hectares	Number of Farmers	Initial Year of Fertilizer Use	Index of Fertilizer Use	Ox:Land Ratio	Man:Land Ratio	Owned Holding	Tenancy	Consumption Units
0-1.99	123	1.00	62.3	1.75	8.36	1.72	58.8	10.29
2-3.99	112	1.94	56.2	.78	1.86	6.54	18.2	2.44
4-5.99	34	2.38	52.1	.59	1.04	11.96	5.8	1.44
6-7.99	4	3.00	42.7	.38	.78	16.56	0	1.11
8-9.99	3	2.33	23.2	.29	.36	15.00	0	.55
10 and +	4	2.50	28.3	.42	.45	40.63	0	.67

> ...that farmers after first trying fertilizers kept on using certain levels because of the pressure or influence of extension agents and not because of the input's objective profitability. Despite its unprofitability, extension agents could persuade farmers to keep on using fertilizers, at least for some time, on the ground that the unresponsiveness of yield to fertilizer is due to the farmers' wrong application rates, lack of adoption of associated cultural practices,...etc. As a result, farmers could keep on using at least some minimal amount of fertilizer hoping that they will finally get significant yield increases (Aklilu, 1976:180).

In support of this interpretation, Aklilu found that of the original 1971 adopters in Bako, 77% had discontinued by 1974, while the comparable figure for Jimma was only 7%.

The Bako study further demonstrated the advantages the larger farmer has in being able to adopt earlier than the smaller farmer. This observation is supported by a significant correlation between a "prosperous farmer" factor (comprised of owned land, cultivated land, level of education, and age) and time of initial fertilizer use. That the prosperous farmer was also the one who was earlier in receiving information about fertilizer use is clearly indicated in table 32.

Table 32. Selected Characteristics of Farmers Classified by Cultivated Land: Bako MPPA, 1974 (Aklilu, 1976:196)

Characteristics	Cultivated Land (hectares) 0-3.99 N=216	 4-7.99 N=54	 8 and above N=7
Index of Fertilizer Use	8.00	23.00	15.00
Time of Initial Fertilizer Use	.36	1.48	2.29
External Extension Contact	3.52	5.78	5.58
Local Extension Contact	1.17	1.22	1.86
Media Exposure	.80	2.37	3.14
Government Exposure Index	6.24	8.35	8.20
Management Knowledge Index	2.62	5.22	7.43
Social Status	1.43	2.50	2.86
Tenancy	114.3	42.0	60.8

CHAPTER VI

SUMMARY OF EMPIRICAL FINDINGS

Fertilizer is increasingly recognized as one of the key inputs in technological packages which can dramatically increase the agricultural productivity of land and labor in the developing countries. Such packages typically include high-yielding varieties of seed (HYVs), fertilizer, and other improved management practices such as pest and weed control. While increased productivity is an essential part of any strategy to keep pace with the world's growing food needs, this can only be achieved through a coordinated effort on the part of agricultural scientists as well as decisionmakers in the public and private sectors. A key actor in this drama is the farmer who is in a position either to continue using traditional technology or, hopefully, to adopt productivity-increasing technology. In view of the importance of fertilizer in helping to achieve such increased productivity, this monograph has attempted to identify and assess the relative importance of the variables and factors which affect the farmer's decision about whether he will adopt fertilizer use.

The review has focused on geographical, economic, and sociological approaches to research on the diffusion of innovations in fertilizer-related agricultural production technology. In general, each of the approaches reviewed was seen to be based on an assumption that a particular variable (or set of variables) is a key factor in determining how quickly an innovation diffuses. Table 33 provides a summary outline of the various research approaches reviewed in Chapters II through V.

As indicated at the outset of this section, there are three distinct, yet interrelated, processes which bear on the farmer's decision making regarding whether to adopt or expand the use of fertilizer. These processes were designated as communication, evaluation, and implementation, respectively. The term communication refers to the passing or flow of information or messages about a particular innovation (e.g., a recommendation to adopt fertilizer use). The term evaluation refers to the criteria used by the farmer to determine whether use of a recommended innovation will significantly increase the profits from his farming operation. Other attributes of the innovation which may be perceived by the farmer as important were also reviewed (e.g., observability, compatibility, reliability, and trialability). Finally, the term implementation is used to refer to those conditions which enable the farmer to combine the resources (e.g.,

Table 33. A Summary of Research Approaches to the Study of the Diffusion and Adoption of Innovations in Agricultural Production Technology

Research Approach[a,b]	Information Output and Empirical Application
A. Geographical Approaches (key variable: spatial distance between potential adopters)	
Monte Carlo Simulation:	Estimation of spatial diffusion of innovations as a function of spatial distance, differential probabilities of the Mean Information Field and other variables (Ramachandran, 1969; Garst, 1972, n.d.). See also Wilbanks (1969), Bigelow (1973), Brown and Lentnek (1973), Rorabacher (1978); and Fitzsimons (1979).
B. Economic Approaches (key variable: profitability of the innovation)	
Logistic Curve Analysis	Estimation of logistic curve's slope coefficient (rates of interfirm or intrafirm diffusion) and relative impact of explanatory variables, notably profitability, on rate of diffusion (Griliches, 1957, 1960a; Martinez, 1973; Mansfield, 1961, 1963; Aklilu, 1976; Shetty, 1966). See also Mangahas (1970), Burke (1978), and Mann (1978).
C. Sociological Approaches (key variable: social differences between potential adopters)	
1. Macrosociological Analysis:	Estimation of impact of differentiation and other structural variables on diffusion of innovations (Bertoli and Young, 1975; Mbithi, 1971; Alao, 1971; Francis, 1971; Koppel, 1978). See also Qadir (1966) for an empirical analysis of compositional effects.
2. Innovativeness Analysis:	Estimation by multiple correlation (Herzog, et al., 1968; Davis, 1968; Ascroft, et al., 1969; Rogers, et al., 1970) or multiple regression (Kolshus, 1974; Colmenares, 1965) of relative importance of correlates of adopter categories or of determinants of temporal diffusion of an innovation, respectively. See also Choudhary and Prasad (1978) and Ashby (1979).
3. Innovation Attribute Analysis:	Prediction of rate of diffusion as a function of farmers' perceptions of innovation's attributes (Fliegel, 1968, 1971; Murthy and Hanumanthappa, 1978; Reddy, et al., 1978; and Jedlicka, 1979a).

(Continued)

Table 33. A Summary of Research Approaches to the Study of the Diffusion and Adoption of Innovations in Agricultural Production Technology (Continued)

Research Approach	Information Output and Empirical Application
D. Other Approaches (no variable assumed *a priori* as key variable)	
1. The Field Experiment	Estimation of which changes in manipulatable variables will be effective in stimulating adoption and diffusion of an innovation (Ascroft, *et al.*, 1973; Roling, 1974b, 1974c; Waterworth, 1980; Bennet and Leonard, 1970; Brown, 1970; Spector, *et al.*, 1971).
2. Tree Analysis: Decision Analysis and Configurational Analysis	Prediction of adoption on basis of modeling farmer decision making and specification of decision criteria and constraints on adoption (Peacock, 1972; Gladwin, 1976, 1977, 1979)
3. Other Multivariate Analysis Procedures	
a. Path Analysis	Estimation of causal ordering of variables and relative weight of parameters determining variation in dependent variable, e.g., adoption (Coward, 1969; Aiken, *et al*, 1974; Ireson, 1976)
b. Probit Analysis	Estimation of impact of change in manipulatable variables on cumulative percent of adopters (Falusi, 1973, 1974)
c. Factor Analysis	Explanation of diffusion-related phenomena on the basis of a reduced set of variables clustering in factors (Aklilu, 1976; Shetty, 1969a; Cameron, 1976; Green, 1971, 1973)

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a. Although not reviewed in detail here, the East-West Food Institute sponsored a series of multination studies on (1) farmer choice and decision making in technology adoption, (2) institutional aspects of technology diffusion, and (3) diffusion and adoption of in-farm technology in commercial and subsistence farming areas. Several reports on these studies are contained in Ahmed and Sadiq (1976). Preliminary findings are reported for Bangladesh (Badruddoza, 1976), India (Nicholson, 1976), Sri Lanka (Amerasinghe), and Thailand (Smuckarn, 1976).

b. Also of interest are studies which focus on the socioeconomic consequences of technology adoption. Examples of this type of study include Rogers and Shoemaker (1971:318-345), IRRI (1975, 1978a, 1978b), Ruttan (1977a), Binswanger and Ryan (1977), Farmer (1977, 1979), Hayami (1978, 1979), Clawson and Hoy (1979), Goodell (1979), Goss (1979), Lowdermilk (1979), Pinstrup-Andersen (1979a), and Gibbons, *et al*. (1980).

land, labor, etc.), institutions (e.g., security of tenure, credit, etc.), and/or capital inputs (e.g., improved varieties, chemical fertilizer) essential for initial use (trial), adoption (continuing use), and expanded use of the innovation. As evidenced by the literature reviewed, different approaches to diffusion research shed varying degrees of light on the relative importance of each of these three processes as constraints to the adoption and diffusion of fertilizer use in the developing countries. The following discussion attempts, in terms of these three general processes, to summarize the diverse empirical findings which emerged in this review of the diffusion research literature. The interested reader may examine supporting studies in greater detail in Chapters II through V.

COMMUNICATION

While diffusion studies conducted by noneconomist social scientists such as rural sociologists, communication specialists, etc., have tended not to take into account or to assess the relative importance of economic variables as potential constraints to adoption, these studies have extensively documented the impact which differential access to information has had in determining which farmers will be earlier (or later) in becoming aware of and adopting an innovation. In turn, such differential access to information is primarily explained in terms of social differences among potential adopters and the way in which informational, credit, and other institutions respond to these differences.

The evidence indicates that farmers having higher social status, as measured, for example, by greater income and larger farm size, tend to become aware of and adopt innovations earlier than smaller farmers. The larger farmer tends not only to have greater exposure to outside sources of information such as mass media, extension workers, and communications with other people but also, as the result of such access, has greater awareness-knowledge and how-knowledge about innovations. Moreover, tending to have more education than the smaller farmer, the larger farmer is better able to use information as it becomes available. However, regardless of size of farm operated, farmers having more participation in social organizations are better able to obtain information through such organizations.

While the tendency for larger farmers to acquire information and adopt such innovations earlier than the smaller farmer results in part from the more advantaged resource position of the larger farmer, the evidence also indicates that the larger farmers are more frequently serviced by institutional sources of information (extension) and capital (credit). As a result, the "trickle down" process of information flow and innovation diffusion may not operate as effectively or efficiently as has been assumed.

The data reviewed prompt the question whether the innovation observed in many studies may have been biased in some way that increased the probability that it would be adopted initially only by the larger farmer. It must be recognized that possibly fertilizer use, _as part of the same technological package that is recommended to the larger farmer_, may not be profitable or as profitable for smaller farmers who operate their farms under less favorable ecological, market, or institutional conditions. Even if appropriate technological packages including fertilizer use are available, the smaller farmer is likely to find that the mass media do not provide relevant information about such packages and that extension workers primarily direct their informational activities toward the larger farmer. Moreover, the smaller farmer may seriously question the credibility or the technical competency of the extension worker as an information source.

When one takes into account that an individual tends to communicate with similar individuals and that those who seek advice from the so-called "opinion leader" may be quite similar to that "leader," one recognizes that information about innovations may not so readily diffuse from larger to smaller farmers or, more generally, from one homogeneous group to another. Indeed, in social systems that have castes, classes, or factions, the likelihood that information will "trickle down" to other strata or to antagonistic groups is considerably reduced. Moveover, "vested interests" may even actively oppose innovations which, if adopted, might accelerate the erosion of their own power base.

In view of these constraints on information flow, the more disadvantaged farmer (e.g., the smaller farmer, the sharecropper, etc.) is likely to be considerably delayed in acquiring awareness-knowledge of and how-knowledge about an innovation such as fertilizer use. When the farmer is aware of an innovation but lacks detailed information about it, he faces considerable uncertainty about the likely performance of the innovation. Therefore, he is likely to imagine that the risks involved in adopting that innovation are greater than they really are. As another possibility, the lack of information about complementary practices (e.g., seeding density) and the failure to adopt them will affect the profitability of using fertilizer and effectively reduce the quantity of fertilizer likely to be used by the farmer.

Even if the smaller farmer acquires the information he needs to properly use the innovation, he may yet encounter difficulties in obtaining the credit and other inputs needed for adoption or face some additional constraint that makes adoption unprofitable. These possibilities are discussed further below in the section on implementation.

EVALUATION

Available empirical evidence supports the hypothesis that an innovation's adoption is influenced by the individual farmer's perception of the innovation's attributes or characteristics. While the importance of profitability is evidenced in numerous studies, attributes other than profitability are also important. Farmers are concerned about the reliability of recommended innovations as compared with the reliability of the technology they currently use. This concern is typically dealt with in the literature in terms of risk and uncertainty. Innovations such as fertilizer use which increase the cash outlay required for adoption are also likely to increase the risk involved in adopting as perceived by the farmer. The smaller farmer, in view of his limited farm size, tenancy, and/or limited access to credit, is in a disadvantaged position, as compared with the larger farmer, to deal with such risk. The smaller farmer consequently had to wait until he believes the risk involved in adopting has been lowered (i.e., until he perceives that the innovation is sufficiently reliable). The amount of time required before a profitable innovation is considered reliable (not "too risky") will depend on how quickly the farmer gets information about its probable performance under conditions similar to those on his own farm. It should be noted that the importance of profitability vs. reliability (risk and uncertainty) as potential constraints to the adoption of an innovation is still being discussed. Further research focused directly on this issue is needed.

In view of the importance of profitability and reliability as well as the acquisition of information in changing a farmer's concepts of an innovation's advantages, it becomes apparent that visual evidence that the innovation will reliably produce a profit is a key variable in determining the rate at which an innovation will diffuse. The farmer's perception of the benefits of fertilizer use will depend not only on the magnitude and consistency of the profits that can be achieved by using this innovation but also on the rate of information flow to the farmer regarding its profitability and reliability.

Another important consideration in evaluating whether to use fertilizer is this input's compatibility with other factors. Basically, this innovation is quite compatible with the farmer's needs or values with respect to providing his family with food and improving the family's standard of living. However, because of various factors (e.g., the farmer's idea that his farm's soil does not require added nutrients, nonavailability of fertilizer-responsive seed varieties, farmer dislike of the taste of the varieties which must be used to obtain a favorable response to added fertilizer, etc.), the farmer may view fertilizer use as not being beneficial or profitable and, thus, as not being compatible with his family's needs and values.

A final attribute which is important in the case of fertilizer use is trialability. In order to conduct a trial of fertilizer use, the farmer must have available land which he can set aside to use for a trial--a step which is easier for the larger farmer than for the smaller one. Of course, the farmer must also believe that fertilizer use is sufficiently profitable and reliable; otherwise, there is little incentive to even try this innovation. Additionally, the farmer must obtain the appropriate inputs, such as fertilizer, seeds, etc., which may have to be ordered in advance and may not be available at the appropriate time. Finally, the farmer must also have the appropriate "how-knowledge" in order to use the fertilizer properly; if he does not combine the inputs correctly, the trial may fail. While the failure may be the result of the farmer's poor management, he may think that the fertilizer is at fault or that the extension agent gave incorrect directions.

It would be difficult to rank these various attributes in terms of their importance because they are considerably interrelated. In general, however, profitability will be important in the long run if the farmer is to initially adopt, continue to use, and increase the quantity of fertilizer applied on his farm. Similarly, fertilizer use must be reliable enough that it does not jeopardize profits. As farmers get experience in using fertilizer, reliability may become less of a concern; thus, its potential importance is more likely to lie early in the diffusion process. For example, where the variation in yield of a fertilized crop is found to be too high, farmers will not adopt the use of fertilizer or they will discontinue it. The other innovation attributes, observability, compatibility, and trialability, appear to have their greatest importance early in the diffusion process. Smaller farmers may delay their adoption of fertilizer use until they get enough information about the profitability and reliability of using fertilizer. The smaller farmer, likely to get little first-hand information from extension workers, will be severely hampered in learning about using fertilizer until other farmers, probably larger farmers, begin to use this innovation locally. Thus, the benefits of using fertilizer are not likely to be obvious to the smaller farmer in the early stages of the innovation's diffusion. This, in turn, will limit the trialability of using fertilizer and delay the time when the smaller farmer can actually begin to use fertilizer.

Once the farmer begins to use fertilizer, the quantity that will be used will be determined by his ability to use fertilizer in a profitable way. In this phase of expansion of fertilizer use, the farmer's management ability as well as fertilizer and crop prices will become particularly important. However, economic or social factors may constrain levels of fertilizer use below those which might be more socially optimal. Labor availability is likely to become a constraint for the larger farmer unless it is profitable to mechanize his operation in some way. Similarly, capital (credit) availability and tenancy are likely to limit the quantity of fertilizer which smaller farmers are able to obtain. The reliability of fertilizer use may continue to be a significant problem in rainfed agriculture where farmers are likely to apply less fertilizer because they feel the risks are higher. Where irrigation is available, farmers can be expected to perceive higher reliability (lower risk and uncertainty) and higher profitability and, accordingly, to use higher fertilizer application rates.

As an example, the case study of the "Do-It-Yourself Rice Kit" in the Philippines shows that a farmer's favorable evaluation of an innovation's attributes can greatly accelerate the rate of diffusion of that innovation. The "Do-It-Yourself Rice Kit" not only reduced the risk involved in trying fertilizer on new varieties, thereby enhancing the perceived reliability of the recommended package, but also made it considerably easier for the farmer to try the new technology and to observe its performance on his own farm. While this case study as well as the Tetu Project in Kenya illustrate the importance of having adequate information available for teaching the proper use of an innovation, the Tetu Project is of particular interest in demonstrating that the diffusion of an innovation can be effectively stimulated by starting from the "bottom up," that is, by starting with the smaller farmer rather than by starting from the "top down," i.e., with the larger farmers.

In view of the importance of the various innovation attributes reviewed, attention should be given to developing a more systematic specification of the range of those attributes that influence the farmer's decision making. This would provide a better understanding of the influence of such perceptions on the diffusion and adoption of fertilizer use. Moreover, improved measures of the farmer's perceptions of fertilizer attributes would provide a better grip on the problem of determining the impact which such variables as farm size, tenancy, and capital (credit) availability have on the adoption of fertilizer use and technological packages which include it. Finally, an improved ability to measure the farmer's perceptions of an innovation would provide a better basis for identifying and estimating the relative importance of the factors which are influential in changing and which can be manipulated in a way that is effective in changing the farmer's perception of an innovation's attributes. Improved knowledge in this respect would considerably facilitate the design of messages and programs that would assist the farmer in learning about, evaluating, and adopting fertilizer use.

IMPLEMENTATION

The various empirical studies reviewed in the economics literature on diffusion research demonstrate repeatedly the importance of an innovation's profitability as a key factor in determining the rate of diffusion of that innovation. Available evidence further demonstrates that the rate of growth of the area fertilized is also influenced by the relative variability of fertilized yields in comparison with unfertilized yields. While the greater yield variability of a fertilized crop tends to increase the uncertainty and risk involved in adopting fertilizer use and to slow the rate of diffusion of this practice, availability of information tends to reduce uncertainty and risk and to accelerate the rate of diffusion. These findings have practical implications in that they point to the importance of developing fertilizer-responsive seeds, fertilizers, and fertilizer use recommendations which increase yields but do not also increase the relative variability of fertilized yields as compared with unfertilized yields. Moreover, these findings also indicate the importance of accelerating the rate at which information is communicated to farmers on the proper use of a recommended technological package (e.g., appropriate rates of application, timing of application, use of complementary practices such as weeding, etc.).

It is also clear from the available evidence that a number of social and economic factors impede the expansion of fertilizer use in a developing country. These factors are now briefly reviewed.

Farm Size

The variable "farm size" tends to be inversely related to the length of time a farmer waits before adopting an innovation. A number of empirical studies suggest that the relationship between "larger" farm size and "earlier" adoption tends to be a function of any or all of the following factors.

Risk

In comparison with the smaller farmer, the larger farmer is better able to invest the additional resources which are usually involved in experimenting with innovations and to undertake the risks involved in such experimentation. For example, a trial of fertilizer use conducted on a 1-hectare plot by a farmer owning 100 hectares is a considerably less risky venture than if a test on a 1-hectare plot is conducted by a farmer who owns only 10 hectares. One may expect that because of the smaller farmer's lesser ability to invest in experimentation and/or to undertake risks he will not try the innovation until enough information is available to reduce the uncertainty and risk involved. Similarly, as compared with larger farmers, smaller farmers may use rates of application that are less than recommended as one way of reducing risk.

Economies of Size in Fixed Transaction Costs

In comparison with the smaller farmer, the larger farmer is in a more favorable position to capture economies of size in transaction costs of acquiring and evaluating information about an innovation, learning about how to use the innovation, and making the necessary purchases. For an increased return of $10 per hectare, the costs of acquiring the necessary information and making the necessary purchases of inputs may be quite worthwhile for the farmer who operates a 100-hectare holding but not for a farmer who operates only 10 hectares. As information about and experience with an innovation become more common in a farming community, fixed transaction costs, at least for information acquisition, will fall. Thus, one may expect that economies of size in fixed transaction costs will occur early in the process of an innovation's diffusion.

Economies of Size in Variable Transaction Costs

In comparison with the smaller farmer, the larger farmer is in a more favorable position to deal in volume and, thereby, to obtain a better price in purchasing inputs and selling outputs.

Policy Discrimination

Finally, the larger farmers are in a more favorable position than the small farmers if, as the result of disciminatory governmental policies, they have readier access to governmentally-subsidized information, credit, or inputs.

While the larger farmer tends to be earlier in adopting an innovation, there is some evidence that smaller farmers who eventually adopt an innovation may eventually use the innovation more intensively than does the larger farmer. The larger farmer has less of an incentive to use fertilizer intensively because he is likely to be able to increase production by bringing additional owned or rented land into production. In contrast, the smaller farmer who may already be renting land is less likely to be able to bring additional land into production and, thereby, has a greater incentive to use fertilizer, a land-augmenting innovation.

Tenancy

The relationship of "tenancy" to the adoption of fertilizer use is one which is highly dependent on a number of intervening variables. Tenancy will tend to be associated with nonadoption of fertilizer use or delay in adopting this innovation where the farmer, not owning title to the holding which he operates and, thus, not possessing the collateral frequently required by institutional sources for obtaining credit, is not able to purchase fertilizer. Additionally, tenants may already be too deeply in debt and may not want to risk additional indebtedness. Finally, alternative sources of credit will likely charge higher rates of interest on loans and thereby make the innovation less profitable and more risky.

On the other hand, the sharecropper tenant may be dissuaded from adopting fertilizer use or from applying fertilizer at a heavier rate than he is currently using if the value of his share of the increased production is less than that of the additional expense which he must pay for fertilizer, labor, etc. to get that additional amount. This will likely be the case where the farmer must pay all the costs associated with introducing new or additional inputs and the landlord pays for none of these costs but yet receives a share of the increased return from the sharecropper's use of such inputs.

Moreover, in situations of insecure tenure (e.g., the tenant farmer holds no written lease on the land he rents from the landlord), if the tenant is able to increase the productivity of his holding by using fertilizer, the landlord may raise the percentage share or fixed amount which the farmer must pay as rent. While data are not available on the prevalence of this problem, the problem's existence in any farming region is not likely to encourage the tenant farmer to adopt an innovation such as fertilizer use which requires the farmer to invest in property he does not own and leaves open the possibility that he will not be able to capture a return large enough to pay him for his inputs (e.g., labor, etc.). In short, in comparison with the owner-operator, the tenant's position is not as sure with respect to any benefit to be derived from building up soil fertility over time.

Finally, where extension services direct their activities primarily to the farmer who is an owner-operator, the tenant farmer is likely to have less access to extension workers as firsthand sources of information about an innovation's existence and its proper use. Thus, the tenant farmer is more dependent on obtaining information about the innovation from local adopters.

These generalizations are tentative and are not stated with the intent of leaving the impression that fertilizer is not being used by tenant farmers in the developing countries. Other factors may be influential (e.g., man-to-land ratio, consumption units in the family, irrigation, special credit programs directed specifically to the smaller farmer, etc.) in increasing the feasibility as well as the economic pressure or incentive to adopt fertilizer usage in spite of tenancy-related obstacles.

Labor Availability

Regarding the variable "labor availability," there is evidence that labor-increasing innovations such as fertilizer use may be used less intensively than they could be if there is a competing labor market which provides employment alternatives at wages higher than or at least competitive with the rate of return to labor from adopting such innovations. On the other hand, labor availability is less likely to be a constraint to adoption where alternative employment opportunities are limited and there is a relatively high man-to-land ratio on farm holdings. Indeed, in those cases where a small farmer (with a small holding and a large family) has a higher man-to-land ratio than a large farmer, the small farmer's need to produce more per acre to feed his family coupled with the high man-to-land ratio on his farm puts considerable economic pressure on him to adopt fertilizer use.

Capital Availability

The variable "capital availability" is inversely related to the length of time a farmer waits before adopting an innovation. As discussed above in relation to farm size, larger farmers are more likely to have available the capital required to try or to adopt fertilizer use, to be more readily able to obtain credit in view of their owned holdings, income, and wealth, and to be in a better position to risk investing in new technology. The smaller farmer, in contrast, particularly if he is a tenant farmer, is less likely to be able to obtain credit from institutional sources and, thereby, less likely to be able to obtain additional funds which can be used for purchasing fertilizer and other inputs.

Water Availability

The variable "water availability" is inversely related to the length of time a farmer waits before adopting fertilizer use and directly related to the quantity of fertilizer applied per hectare. Effective and efficient use of fertilizer is facilitated by the timeliness and adequacy of supply of water to the fertilized crop. Farmers having access to irrigation clearly have an advantage with respect to adopting fertilizer use in comparison with farmers who are dependent on rainfall for water. Farmers not having access to irrigation are likely to see the risk in adopting fertilizer use as being greater and may encounter greater difficulty in obtaining credit for the purchase of fertilizer.

Market-Related Constraints

Even assuming that sufficient fertilizer is available in the market to permit the individual farmer to purchase all the fertilizer that he requires, other market-related factors may operate as economic constraints on the adoption of fertilizer use. In some cases, farmers may face economic constraints in the form of inability to make a profitable return from using fertilizer on crops which the government maintains an artificially low price ceiling. Such policies are particularly discriminatory against those farmers who already face higher per-unit costs of production or incur greater risks in adopting a new technology. Another type of market-related constraint and one which may significantly increase the cost per unit of producing and selling a fertilized crop is the higher transportation costs which some farmers face in moving supplies and products between the market and farm. In some situations the costs associated with transportation may be so prohibitive as to dissuade the farmer from even attempting to adopt.

As an empirical example, Aklilu's (1976) study of the expansion of fertilizer use in Ethiopia points not only to the importance of variability among districts in the profitability of using fertilizer as a potential constraint to its adoption but also that such variability is inversely related to the degree to which seed varieties are adapted to the agro-climatic areas for which they have been recommended. Even in districts where fertilizer use is basically profitable for a large majority of the farmers, an accelerated rate of diffusion may yet be impeded not only by constraints on information flow but also by constraints such as farm size, tenancy, and capital (credit) availability which prevent or dissuade the farmer from adopting or, in response to which, farmers use less fertilizer than would be economically optimal. Perhaps more clearly than in any of the other studies reviewed, Aklilu's (1976) analysis of the expansion of fertilizer use in Ethiopia indicates that social or economic pressures, from such factors as small farm size or tenancy (which imply a land constraint) and higher consumption units (which implies a greater dependence on the farm for the family's food supply), may encourage the farmer to adopt fertilizer use but these pressures are not sufficient to determine whether or not fertilizer will be used. Thus, adoption depends on the farmer acquiring awareness and how-knowledge about fertilizer use. However, the adoption of fertilizer use also depends on (1) the complementarity of this practice with available resources, (2) whether the farmer is able to obtain credit, (3) whether fertilizer and other inputs are available in the market, and (4) whether the farmer can profitably market a fertilized crop.

SUMMARY

In general, the constraining effect which most of the economic or social factors reviewed have on the rate of diffusion of fertilizer use is that of making this innovation more profitable and less risky for some farmers *and* less profitable and more risky for other farmers. Because of the larger farmer's greater ability to deal with risk or because such farmers have better information and perceive less risk in adopting than does the smaller farmer, larger farmers are generally earlier in adopting. However, as smaller farmers begin to acquire information about the innovation and are able to observe the performance of the innovation on the farms of earlier adopters, they will begin to adopt if there are no constraints to prevent or discourage such adoption. Indeed, given an adequate supply of labor, particularly family labor, as well as access to credit, the smaller farmer may soon be using fertilizer more intensively than the larger farmer.

On a regional scale, the diffusion of fertilizer use will be *accelerated* in areas where markets and infrastructure are better developed and where irrigation is available to farmers in varying classes of farm size and *delayed* or *dampened* in the extent to which tenant and smaller farmers are unable to obtain credit or face other constraints (e.g., lack of irrigation). This general trend of events presupposes that the innovation is basically profitable to farmers regardless of farm size. However, if profitable use of fertilizer is dependent on its use in conjunction with fertilizer-responsive seed varieties and such varieties are not available in an area, then the level of adoption, both in terms of percentage of users and rates of application, will remain low until such fertilizer-responsive seed varieties become available.

The problem with developing hard and fast statements which specify precise relationships between specific factors (e.g., farm size and adoption of fertilizer use) is that the factor(s) in question may or may not be a constraint to adoption depending on the presence or absence of one or more of the other potential constraining factors. It is therefore difficult to draw generalizations that will be consistently valid from one developing country to the next. But the frequency with which such factors as profitability, farm size, information availability, etc., reappear from one diffusion study to the next as significant constraints to adoption demonstrates that the specific constraints operative in any particular case are likely to come from a more general pool of potentially influential variables.

Figure 7 provides, on the basis of the literature herein reviewed, a summary listing of such a general pool of variables or factors which potentially influence the rate of diffusion of fertilizer use in a developing country. The importance of a summary listing such as is represented in figure 7 cannot be sufficiently emphasized. By reference to such a checklist of the factors or variables which in any particular situation may be operating to facilitate or constrain the adoption of fertilizer use, a diffusion researcher is more likely to be careful to design an adoption or diffusion study that will provide information on the full set of variables which may be influencing a farmer's decision regarding whether to adopt or expand fertilizer use. If such care is not exercised, key variables or constraints will likely be neglected and policies recommended on the basis of that research may fail to address key constraints which need to be relaxed. Additionally, meaningful comparisons of and conclusions about the general nature of empirical findings from different studies will be seriously hindered.

Several considerations suggest that the checklist provided by figure 7 is sufficiently comprehensive to deal with the circumstances prevailing in a specific geographic region of any developing country. These points include: (1) The list is based on empirical studies conducted in more than 25 developing countries in Africa, Asia, and Latin America. (2) The list is based on empirical findings drawn from studies conducted by social scientists in such diverse disciplines as geography, economics, and sociology. (3) Many of the variables or factors identified as potential constraints to the adoption of fertilizer use are the same factors which affect the diffusion of other types of innovations in agricultural production technology. (4) The constraints to expanded use of fertilizer identified in this review are similarly identified by Alix (1972), FAO (1977), Jha (1978), Abbott (1979), and Lewis and Isherwood (1979) as potential constraints to expanded use of fertilizer in the developing countries. Thus, specification and testing of models including the variables listed in figure 7 would likely be successful in improving our ability to explain and predict farmer decision making regarding whether to try, adopt, or expand fertilizer use.[58]

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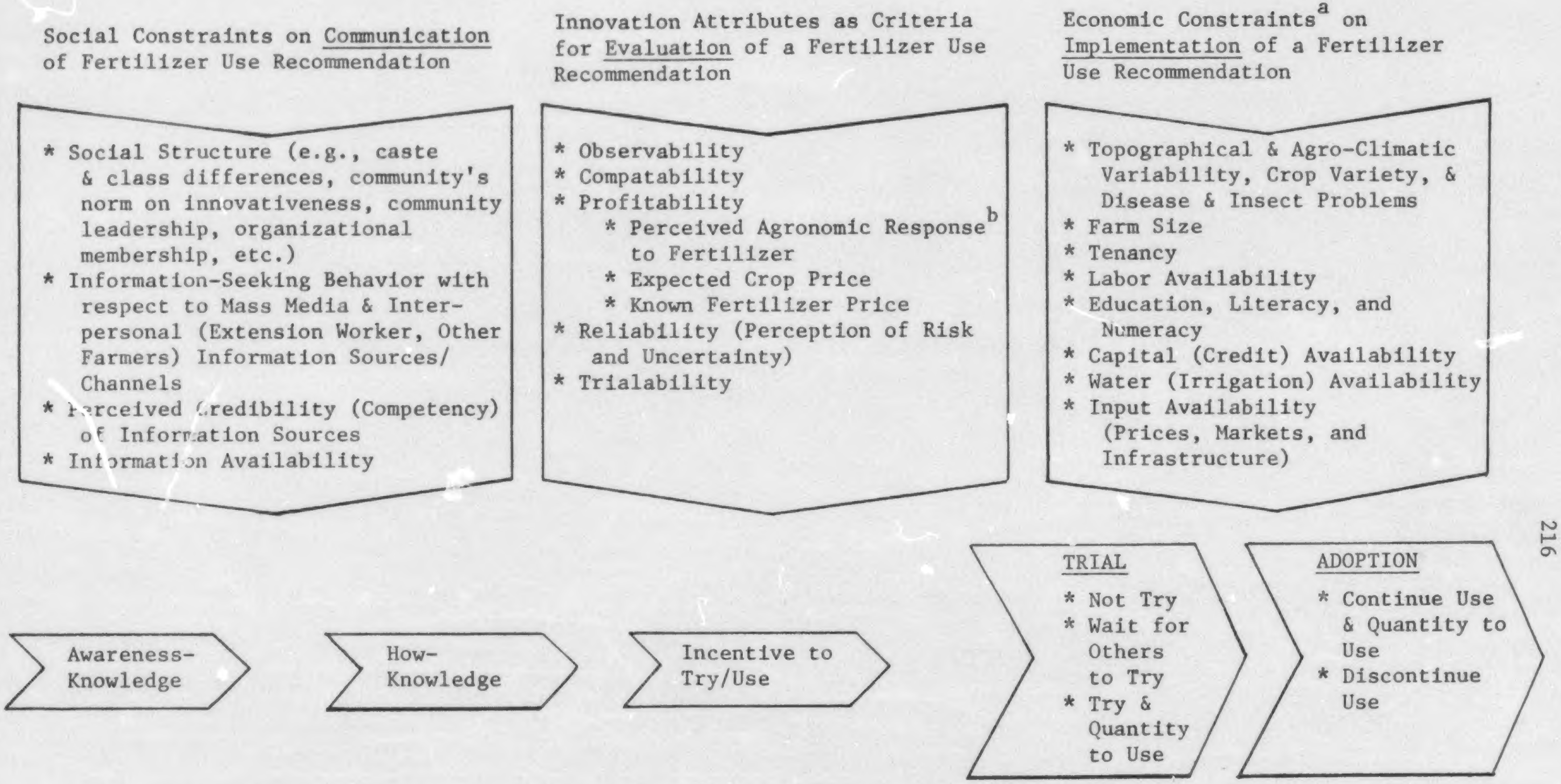
[58] As of this writing, the International Fertilizer Development Center (IFDC) had undertaken a research project on Fertilizer Adoption/Demand in the developing countries (Sidhu, et al., 1978). See also Ahsan and Shotelersuk (n.d.).


Social Constraints on Communication of Fertilizer Use Recommendation
* Social Structure (e.g., caste & class differences, community's norm on innovativeness, community leadership, organizational membership, etc.)
* Information-Seeking Behavior with respect to Mass Media & Interpersonal (Extension Worker, Other Farmers) Information Sources/Channels
* Perceived Credibility (Competency) of Information Sources
* Information Availability
Innovation Attributes as Criteria for Evaluation of a Fertilizer Use Recommendation
* Observability
* Compatability
* Profitability
* Perceived Agronomic Response[b] to Fertilizer
* Expected Crop Price
* Known Fertilizer Price
* Reliability (Perception of Risk and Uncertainty)
* Trialability
Economic Constraints[a] on Implementation of a Fertilizer Use Recommendation
* Topographical & Agro-Climatic Variability, Crop Variety, & Disease & Insect Problems
* Farm Size
* Tenancy
* Labor Availability
* Education, Literacy, and Numeracy
* Capital (Credit) Availability
* Water (Irrigation) Availability
* Input Availability (Prices, Markets, and Infrastructure)
Awareness-Knowledge
How-Knowledge
Incentive to Try/Use
TRIAL
* Not Try
* Wait for Others to Try
* Try & Quantity to Use
ADOPTION
* Continue Use & Quantity to Use
* Discontinue Use

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a. Economic constraints could also be referred to as structural or task environment variables.

b. Agronomic response is directly influenced by topographical and agro-climatic variability, crop variety, and disease and insect problems.

Figure 7. A Summary of Potential Constraints to the Adoption of a Fertilizer Use Recommendation in a Developing Country.

CHAPTER VII

POLICY IMPLICATIONS

A range of policy implications emerge from this monograph's review of and conclusions about the factors determining the rate of diffusion of fertilizer use in the developing countries, particularly among smaller farmers who have increasingly become a major target group in development assistance efforts. No attempt will be made here to suggest which policies should be applied in any specific country. The choice of the appropriate policy for an individual country and at a particular time will depend on prevailing circumstances and the associated costs and expected benefits from alternative measures. However, general guidelines can be provided regarding the pros and cons of a wide range of measures. Such guidelines are primarily based on experiences in countries where the particular policies have been applied.[59]

Fertilizer is not the sole input which smaller farmers are likely to require in order to increase the productivity of the land they farm and to make small farm agriculture a going concern. At the same time, however, national governments must recognize that fertilizer is one tool which, if properly used, can have a significant developmental impact for both the smaller farmer and the economy as a whole. Whether this tool will be used by the farmer will depend primarily on whether government officials adequately understand that accelerated diffusion of fertilizer use depends not only on agronomic response to fertilizer, fertilizer and agricultural product prices, and a range of potential economic constraints but also on the rate at which potential adopters receive information about how to use this input profitably. Thus, successful government policy aimed at accelerating the rate of diffusion of fertilizer use must not only provide the farmer with an economic incentive to adopt fertilizer use but also ensure that farmers acquire adequate information regarding how to profitably respond to such incentive.

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59. This section on policy implications draws in part on material from a working draft document on policies relating to fertilizer use (IFDC, 1976), prepared by Dr. Per Pinstrup-Andersen, during the period that he was Director, Agro-Economic Division, International Fertilizer Development Center.

FACILITATING COMMUNICATION: RELAXING SOCIAL CONSTRAINTS TO INFORMATION FLOW

Smaller farmers, as well as the extension workers on whom such farmers are dependent for information about yield-increasing innovations, such as fertilizer use, are frequently poorly informed about the kind and quantity of fertilizer to use and how and when to apply it. Many farmers, for example, have not heard of soil testing. Government policy is needed to support agronomic research that will generate information adequate to guide farmers as to the type of fertilizer needed, as well as the optimum rate, timing, and placement of application under various agro-climatic and economic conditions. Government policy is also needed that ensures that steps will be taken through education, social participation, and extension to provide farmers an opportunity to learn about the yield-increasing effect of using fertilizer and the steps which are involved in achieving such increased yields.

A government's policies regarding the level of education that it will seek to provide the country's rural population will significantly influence, over the long run, the level of literacy and indirectly the farmer's managerial ability to utilize information about new technology and commodity and input prices and relate this information to the particular needs of his own farming operation. Consequently, in the long run, governments in the developing countries should continue to strive, through appropriate educational programs, to improve the levels of literacy in their rural areas.

In the areas of social participation and extension, policies are needed that will encourage the development of communication systems which accelerate the rate of dissemination of information about yield-increasing innovations such as fertilizer use. Such systems may include the development of farmer training courses at a district or village level; the development of a network of smaller farmers who will cooperate as testers and demonstrators of new technology and who also will be able to discuss the benefits and appropriate use of the new technology with other farmers; and illustrated and readily understandable pamphlets or posters which the farmer can use as a source of information about the use of purchased inputs. An improved availability of information increases the farmer's opportunity to learn about the economic return from adopting and using an input such as fertilizer. Through such communication channels or from such information sources, farmers can learn how to use an improved technology's inputs and practices. This enables them to acquire the improved managerial ability and skills necessary for the profitable adoption of fertilizer use and increases the prospects for efficient use of fertilizer.

Since the agronomic response to fertilizer on a specific farm will be influenced by the agro-climatic conditions prevailing in the region, information dissemination systems should be designed on the basis of field level research which identifies the factors constraining yields in that region and tests alternative technological packages before deciding which should be recommended for use by farmers. Once researchers are sufficiently confident of their recommendations, the recommendations can be further tried or tested on the farms of cooperating farmers. If the recommendations are again successful on these farms, policies and programs are required that will encourage other farmers in the region to also try the recommendations. In the case of a trial of fertilizer use, the government and/or fertilizer firms in the private sector can facilitate trials by making readily available to farmers the precise quantity of fertilizer and any other inputs needed to conduct a trial. The necessary materials for a trial--fertilizer, other inputs such as the recommended variety, and information on the proper use of these inputs--can be made available as a "package" as in the case of the "Do-It-Yourself Rice Kit" in the Philippines. Such an approach would not only enhance the trialability of fertilizer use but also the opportunity for the farmer to see whether the recommended technology performs satisfactorily on his own farm. As farmers gain experience in profitably using fertilizer, they can, from one cropping season to the next, seek ways of moving even closer to the optimum level of use of fertilizer--a level which will fluctuate from season to season depending on current inputs, including the prices of fertilizer and agricultural products.

A network of farmers who cooperate in a test demonstration program could provide one basis for organizing farmers into a group which could arrange for a single or group loan from an institutional credit source. Such a loan would be used to purchase fertilizer which, in turn, would be divided among the group's members. Each farmer would be obliged to repay his portion of the loan in order to be eligible to receive a loan in the subsequent cropping season. The existence of such a group would also facilitate the flow of information from extension workers to the group leader and, in turn, to other group members. Of course, other organizations of a religious or social nature may already exist in a farming region and such organizations could also be mobilized to facilitate an accelerated flow of information about fertilizer use.

Another approach to increasing the farmer's awareness-knowledge and how-knowledge about fertilizer use, as well as the farmer's knowledgeability about available credit programs and existence of groups through which credit for fertilizer can be obtained, is to make more productive use of mass communication channels such as radio and newspapers. More detailed information on effective communication with farmers in the developing countries is available in Crawford and Williams (1974), Diaz-Bordenave (1977), Rogers, et al (1978), and Sagasti (1978). Evaluations of communication programs aimed at farmers in specific developing countries are reported for India (e.g., Singh and Singh, 1976), Kenya (Leonard, 1977), and Guatemala (O'Sullivan-Ryan, 1978; Ray, 1978; Rich, et al, 1978; and Nesman, et al, 1979).

In designing programs to communicate information about fertilizer use to farmers, agricultural research and extension workers must take into account that a particular fertilizer use recommendation will be viewed differently by various farmers depending on the particular circumstances of their farming operations. When an agricultural research and extension service is attempting to introduce a fertilizer use recommendation in an agricultural area characterized by a heterogeneous mix of farmers, it is well to bear in mind that effective change programs can only be designed for homogeneous categories of people. As Roling (personal communication) emphasizes:

> One does not give matrix algebra to a mixed group of children from the primary and secondary school. Instead, they are carefully segmented into grades, forms, ability levels and so on, while the content and method of teaching are carefully designed to fit the developmental level of the segment concerned. Notwithstanding the logic of this approach, rural, and especially agricultural, development programs and projects present a uniform package to "the" farmer, regardless of his farm size, his relative factor costs and his access to resources.

As an alternative to conventional approaches, Roling proposes the "segmentation" principle (Tull and Hawkins, 1976), by which farmers in a program or project area are "segmented" into categories which are homogeneous in terms of access to land, labor, capital, inputs, markets, and information. Such segmentation may be accomplished by a random sample survey of the agricultural area in which research and extension activities are to be undertaken to increase adoption and use of fertilizer-related practices and/or packages. The survey would provide sufficient information on the location and characteristics of farmers to permit the identification of homogeneous groups for which specific fertilizer use recommendations could be tailored. This approach, illustrated in figure 8, would facilitate a more direct dissemination of information about an innovation to the smaller farmer than if it were assumed that a "trickle down" process would ensure that even the least progressive farmer would eventually receive the information from more progressive farmers.

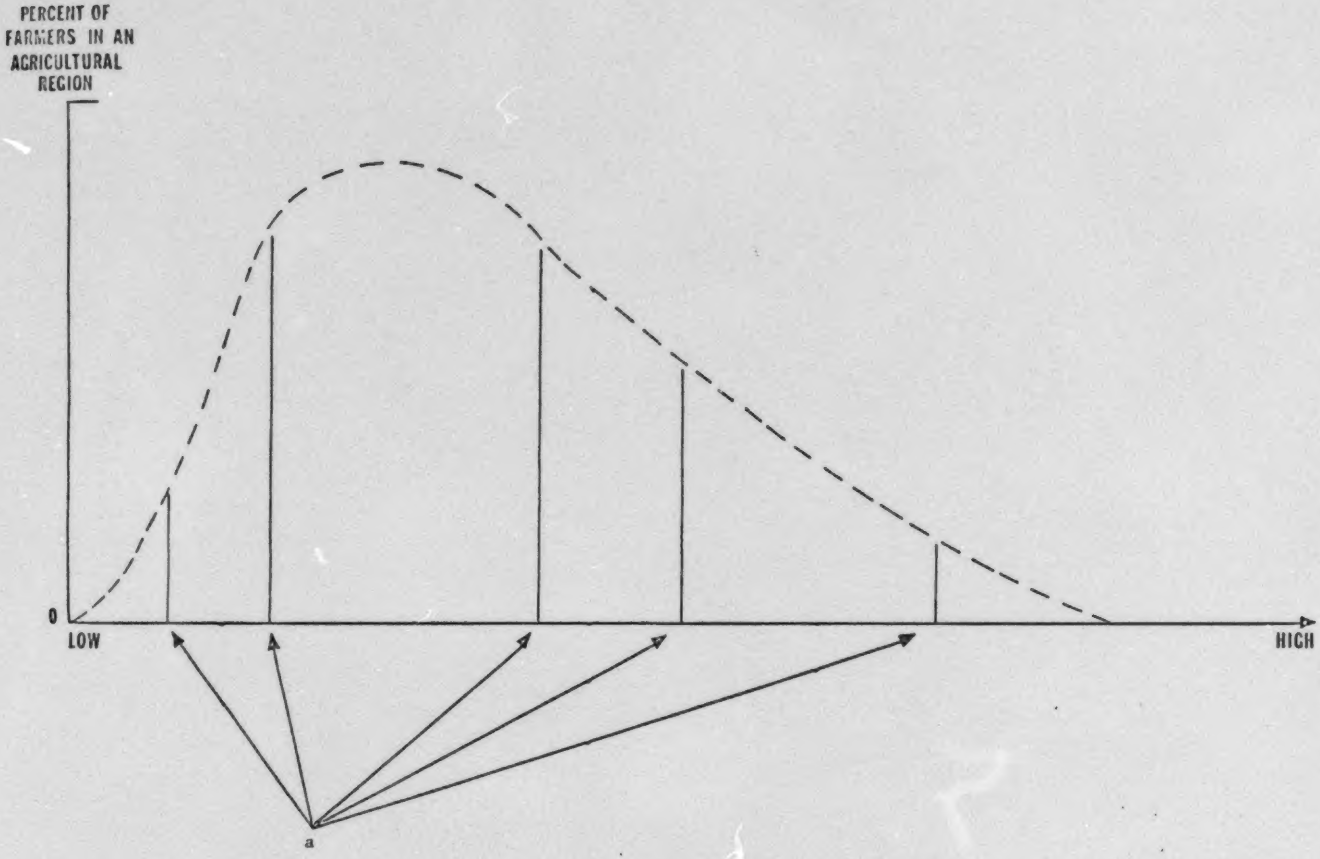
An important social or communication variable which frequently acts as a constraint to the flow of information about an innovation is the level of competency or credibility which the farmer considers his information sources to have. This variable appears to be particularly important in the relationship between the extension worker and the smaller farmer. Policies aimed at developing and supporting programs that provide an extension worker with an opportunity to improve his technical competency, as well as competencies in the areas of farming, economics, science, and communication, would make him a more valuable source of information not only for the farmer who is seeking information about ways to improve his land's productivity but also for the research worker who is seeking information about the nature of farm-level problems (e.g., the factors which are prevalent as constraints to increased yields).

FACILITATING EVALUATION: INCREASING ECONOMIC INCENTIVE

Economic incentives for the farmer are enhanced by increasing the agronomic response to fertilizer (higher yield per hectare), by maintaining a favorable fertilizer-commodity price ratio, and by relaxing existing economic constraints.

Increasing Agronomic Response

The agronomic response to fertilizer depends on numerous factors, including soil characteristics; crop variety; climatic variables such as the amount and timeliness of water supply; diseases and insects; nutrient balance of fertilizer; and the



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a. Cut-off points are arbitrary and depend on which variable (or combination of variables) is used to segment the population of farmers. Criteria variables for segmentation could include, but are not limited to, the following possibilities: access to land (farm size and tenancy), irrigation, labor, capital (credit), inputs, markets, and information; education; level of technology used, etc.

Figure 8. Example of the Population of an Agricultural Region Segmented into Relatively Homogeneous Target Groups.

timeliness of application and placement of fertilizer. Government policy can be indirectly effective in increasing agronomic response to fertilizer by facilitating research to modify one or more of the above-mentioned factors (e.g., development of more fertilizer-responsive varieties of seed, improved pesticides, better irrigation, etc.) and to develop more efficient fertilizer materials and application methods.

Reducing Fertilizer Prices to Farmers

Unless certain constraints, discussed further below, are present which prohibit adoption of fertilizer use, the rate of diffusion of fertilizer use can be accelerated through the lowering of fertilizer prices. The price elasticity of demand provides a convenient measure of the relationship between a change in price and the corresponding change in the quantity of fertilizer that will be purchased and is expressed as the percentage change in quantity purchased associated with a one-percent change in price. Although the price elasticity of demand for fertilizer was not developed as a basis for estimating the impact of price policies on the rate of diffusion of fertilizer use, Timmer (1974:221) has estimated that for each 10% reduction in the price of fertilizer in many developing countries, the quantity of fertilizer purchased would tend to increase by 5% to 10% in the short run and by two to three times this amount in the long run. While farmers who are currently using fertilizer are likely to be responsible for some of the increased amount of fertilizer purchased, it may also be the case that some of the additional fertilizer purchased is being bought by farmers who are using this input for the first time. Consideration of this possibility suggests that government policies aimed at reducing the price the farmer must pay for fertilizer is likely to accelerate the rate of diffusion of fertilizer use. Government policies aimed at increasing efficiency in the production and marketing of fertilizer provide one potential source for lowering fertilizer prices at the farm level. Alternatively, foreign trade policies aimed at the protection of domestic fertilizer mining and manufacturing may maintain the farm level price of fertilizer higher than it would be under more competitive circumstances; in turn, such a higher price will reduce the profitability of using fertilizer and, thereby, adversely affect the rate of diffusion of fertilizer use. With such possibilities in mind, we now turn to a consideration of policy implications in the area of direct government intervention.

Direct Price Subsidies

Direct price subsidies for fertilizer are very common in many developing countries and provide one means of stimulating the rate of diffusion of fertilizer use. While such subsidies may be implemented in a number of ways, sufficient control must be maintained to ensure that the subsidies are in fact being reflected in the price which the farmer pays for fertilizer.[60] Although a permanent price subsidy is likely to result in excessive costs, a selectively applied price subsidy can be used to stimulate the adoption of fertilizer use by those farmers who have previously never used fertilizer, have planted crops that will respond favorably to fertilizer, and have access to a market in which they can profitably sell the surplus production from the fertilized crop. In view of the greater risk the farmer is likely to think is involved in using fertilizer, the price of fertilizer may have to be somewhat lower for the farmer who is purchasing fertilizer the first time or for the first few purchases than for the subsequent purchases of more experienced fertilizer users.

Also, in countries with high domestic fertilizer prices resulting from underutilization of installed production capacity, a temporary and selectively applied subsidy program may be particularly effective in accelerating the rate of diffusion of fertilizer use both among farms and within individual farms. As the rate of diffusion of fertilizer use begins to accelerate and the level of production of fertilizer begins to rise, a country's level of fertilizer production will begin to move closer and closer toward full production and the lower costs per unit would enable fertilizer to be sold at a lower price which would reduce or eliminate the need for a continuation of the subsidy program. A problem with such subsidies, however, is that once introduced they tend to be difficult to phase out.

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60. If a price subsidy program is being used primarily to sustain relatively high levels of use of fertilizer by farmers who are already using fertilizer, such a program will tend to be large and very expensive. In this situation, unless policies are implemented to simultaneously expand fertilizer supplied, a price subsidy program may be sufficiently large that it results in fertilizer scarcities. If this occurs, the potential increase in usage of fertilizer expected as a result of the price subsidy will only be partially realized.

Indirect Subsidies

There are a number of other ways in which subsidies can effectively reduce the real price of fertilizer.[61] A common approach is to make credit available to farmers at a subsidized interest rate. Where lack of credit at a reasonable rate of interest is a major constraint to adoption, a subsidized credit program may be effective in accelerating the rate of diffusion.[62] Such subsidization, however, is costly and points to the need for less costly alternatives, such as removing the factors leading to the high interest rates associated with credit for purchasing fertilizer or expanding the supply of credit albeit at a higher rate of interest. High interest rates on credit and reluctance among commercial banks to provide agricultural credit are probably in large part associated with risk and uncertainty in agricultural production and lack of credit security. Government policies oriented to reducing risk and uncertainty, i.e., to increasing the reliability of using fertilizer, or to providing greater security of tenure in a way that will facilitate the farmer's access to credit are likely to provide higher benefits than subsidized interest rates.

Price Differentiation

The contribution of fertilizer to agricultural production and development may also be increased in part through a reallocation of available fertilizer among crops and regions. A number of countries have applied two-price systems to accomplish such aims. The difficulty of controlling the actual use of fertilizers, however, suggests that government intervention in product prices may be more effective.

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[61] Other indirect subsidy programs include tax concessions, preferential exchange rates, preferential freight rates, etc.

[62] Although a free market system's allocative mechanism does not necessarily operate perfectly, there is a tendency in a free market for capital to be allocated to those areas of investment where the highest returns can be obtained. Thus permanent subsidization of credit for fertilizer may involve a considerable cost to society because returns to limited capital are reduced.

Increasing Agricultural Product Prices Paid to Farmers

Agricultural price support policies are aimed at increasing agricultural product prices above free market prices to stimulate increased production. Other things equal, such increases in product prices increase the incentive for farmers who previously have never used fertilizer to now begin to use this input on those crops for which there are price supports.[63] Many developing countries, however, are faced with severe nutritional deficiencies among considerable segments of the population. Even where malnutrition is not a major problem, food costs are likely to be a large portion of family income. In such countries, the food price level is extremely important in the development process. Under such conditions, policies aimed at increasing agricultural product prices may not be in the best interest of the individual country if, as would usually be the case, the burden of price increases is largely passed on to the low-income consumer.

FACILITATING IMPLEMENTATION: RELAXING ECONOMIC CONSTRAINTS TO ADOPTION

An accelerated rate of diffusion of fertilizer use may be impeded by the presence of any or several of a number of economic constraints to adoption of this innovation. Such constraints can sufficiently reduce profitability to the point that the farmer is dissuaded from even making an initial trial of this practice. The specific constraints operating in one country and their relative impact on the rate of diffusion of fertilizer use will vary among geographical regions and among farms within regions. However, in general, smaller farmers tend to be faced with more severe constraints than larger farmers.

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[63] Since prices are above the free market equilibrium between supply and demand, the latter policies tend to create a surplus of agricultural products. Such surplus must be removed from the market to maintain the higher price. While the cost of the higher prices may be passed on to the consumer, the cost to government of surplus removal can be high as experienced by the United States during the 1950's.

Effective easing or relaxing of constraints requires appropriate governmental policies which are based on a knowledge of which constraints prevail among the farmers toward which the policy is aimed and how such constraints interact and affect the pattern of diffusion of an innovation. While the presence and impact of individual constraints are location specific, a number of economic constraints to the adoption of fertilizer use are likely to be present in many developing countries. These include risk and uncertainty, lack of complementary inputs, unavailability of fertilizer, lack of credit, and tenancy and farm size. Policy measures aimed at reducing the impact of each of these constraints are discussed below.

Risk and Uncertainty

This monograph has stressed the importance of reliability as a key attribute which farmers in the developing countries take into account in their decision making about whether to adopt a recommended innovation. Smaller farmers, in particular, face numerous natural or environmental as well as market factors which from the farmer's viewpoint, reduce the reliability of fertilizer use. Thus, the smaller farmer is likely to perceive greater uncertainty and risk in adopting fertilizer use than in continuing to use the technology he already practices. Irregularity in the pattern of rainfall and disease and insect attacks are the most important natural or environmental factors which increase risk and uncertainty. Policies which facilitate the development and diffusion of seed varieties that are disease resistant and responsive to fertilizer in specific agro-climatic regions provides one means of reducing risk. Expansion of irrigation into areas with unfavorable rainfall patterns is another potential source for reducing risk. Where there are deficiencies in varieties and/or rainfall, improved management practices and the farmer's ability to utilize such practices become even more important as potential sources for reducing risk.

While upward fluctuations in fertilizer prices may reduce the quantity of fertilizer used, such fluctuations *per se* are not likely to increase risk because the farmer typically knows the actual price of the fertilizer available for purchase and he can react accordingly. However, the possibility of downward fluctuations in agricultural product prices does increase uncertainty and risk because the farmer's investment in the purchase of fertilizer is made before the actual product price is known unless, of course, either a governmentally set price is known in advance (i.e., at the time the farmer is ready to purchase fertilizer) or the farmer has contracted a price for the sale of all or some of his harvest. As the most profitable quantity of fertilizer to purchase will depend partly on the product price, farmers who anticipate large product price fluctuations are likely to either not adopt fertilizer use or to limit their purchase of fertilizer to that quantity that corresponds to the optimum quantity at relatively low product prices. Similarly, the pursuit of a "cheap food" policy in behalf of urban consumers will be reflected in lower product prices paid to farmers for their produce, thereby reducing the incentive for the farmer to adopt or use heavier rates of application of fertilizer.

Consequently, if a government seeks to structure the economic or market environment in a way that will increase production of food and other agricultural commodities through an accelerated diffusion of fertilizer use, policies should be formulated which facilitate stabilization of product prices at a level that will be sufficiently profitable for the farmer to adopt fertilizer use or to increase the quantity of fertilizer which he is using. As indicated earlier, however, the problem in setting product prices at such a higher level is accomplishing it so as to not penalize lower-income urban consumers. When such considerations are taken into account, one realizes that achievement of an accelerated diffusion of fertilizer use will also partly depend on appropriate governmental policy in the area of wholesale and retail food marketing.

Lack of Complementary Inputs

As an important step toward increasing the compatibility, profitability, and reliability of using fertilizer in small farm agriculture, policymakers in the developing countries must ensure that agricultural research is oriented toward developing technologies which are (1) adapted to the particular agro-climatic regions in which small farmers operate and (2) highly responsive to fertilizer under the agro-climatic conditions in those regions. If traditional varieties or new varieties are not fertilizer-responsive, such policies as guaranteed commodity prices, subsidized fertilizer prices, reduced interest rates on credit, or an expanded supply of credit are not likely to be effective in accelerating the rate of diffusion of fertilizer use.

Where fertilizer-responsive varieties have been developed, policies are also needed to ensure that such varieties and appropriate other inputs (e.g., pesticides, herbicides, machinery, etc.) are available within the area where the farmer normally shops.

Unavailability of Fertilizer

For the economically sound use of fertilizer, the right kind must be available to the farmer in the market before the time it is to be applied on the farm. This basic requirement, however, is frequently not met in many developing countries. Governments can increase the availability and timeliness in the supply of fertilizer by encouraging the establishment of sales outlets and by increasing accessibility to such outlets through improved road and transportation systems. Policies aimed at providing or improving farm-to-market roads and transportation systems will, in conjunction with policies to improve the availability of fertilizer-responsive seed varieties, fertilizer, and credit, significantly increase the economic incentive for those farmers who do not use fertilizer to adopt its use. However, it should be emphasized that any activities expected to increase the demand for fertilizer (e.g., price and credit subsidies) should be accompanied by policies to increase the supply of fertilizer available enough to meet such demand increases. If this consideration is overlooked, the results will be fertilizer scarcities, black market developments, and limited success in accelerating and sustaining diffusion of fertilizer use.

Lack of Credit

The one single constraint to adoption of fertilizer use or other innovations in agricultural production technology most frequently mentioned by farmers is lack of credit. While this factor is undoubtedly important and policy measures have been suggested for relaxing this constraint, farm surveys may grossly overstate its significance in any particular farming region. The likelihood that other constraints may also be present suggest the possibility that a large proportion of the farmers who stated that lack of credit is a reason for not adopting fertilizer use would possibly not use fertilizer even if provided with credit for purchasing it. Risk and uncertainty, low product prices, and unavailability of fertilizer or complementary inputs are frequently the real reasons credit is not sought and obtained. However, where credit is indeed a constraint to adoption, an expansion of the supply of credit will accelerate the rate of diffusion of fertilizer use if it is selectively made available to farmers who are planting fertilizer-responsive varieties. Experience to date in various developing countries also suggests that governmental policies and programs may be needed to provide sufficient guarantees to suppliers of credit and to limit the consequences of crop failure to the farmer.

Tenancy and Farm Size

Fertilizer use as a land-augmenting innovation is potentially a highly profitable innovation for the farmer who has a small holding and who may be either a fixed-rent or sharecropper tenant. But such a small farmer is particularly at a disadvantage with respect both to obtaining the credit needed to purchase fertilizer and other inputs and retaining a profitable return on any investment he makes in such inputs. For example, sharecroppers often pay for all inputs, including fertilizer, and deliver a portion of the harvest as rent to the landlord who has paid for none of the inputs. Thus, the tenant gains only a portion of the return on his investment in fertilizer and other inputs which, in turn, means that the economic optimum quantity of fertilizer and complementary inputs for the tenant farmer is less than if the farmer is the owner or pays only a fixed rent.

In contrast to farmers who own the land which they operate, tenant farmers are also likely to be subject to considerable uncertainty about the future which stems from insecure tenancy arrangements (e.g., no written contract between tenant and landlord). The tenant farmer is left in a position where the landlord can, at will, increase the fixed amount or share which the tenant must pay as rent. The problem of uncertainty is confounded even more when government plans call for land reform and redistribution of land, but there is yet one delay after another in the implementation of such plans. Governmental policy aimed at promoting or forcing greater security of tenure (e.g., written contracts), fixed rent rather than share rent, and cost- as well as output-sharing between sharecropper tenants and landlords, not only will increase incentive to use fertilizer but also will accelerate the rate of diffusion of fertilizer use.[64]

A GENERAL PERSPECTIVE ON CONSTRAINTS

The variables in figure 7 are primarily policy-relevant variables, i.e., variables which either should be taken into account in formulating policy or which are subject to change if appropriate policy and/or program variables are manipulated. A partial listing of such policy and/or program variables and their general relationship to the variables or factors included in figure 7 is presented in figure 9. The manipulatable variables included in figure 9 indicate a range of variables which, if properly manipulated, would be expected to accelerate the rate of diffusion of fertilizer use in a developing country. However, without specific data on the relative impact which various constraints have on the diffusion of fertilizer use in a particular country, the relative importance of the different manipulatable variables for stimulating accelerated diffusion remains a matter for additional research.

Even when taken together, figures 7 and 9 are limited in that they are only checklists of limited scope and provide little assistance in developing the combination of policies and programs that would accelerate a more effective utilization of fertilizer at the small farm level. If anything, the listing of potential constraints in figure 7 should serve to reemphasize that adoption of fertilizer use and increased demand for fertilizer may be impeded by a broad range of factors which, as illustrated by figure 9, may require a broad response in terms of appropriate policies and programs on the part of the public and private sector. Identification of the appropriate mix of policies and programs to effectively deal with the range of possible agro-economic and socio-economic constraints existing in a specific agricultural region will depend on a means of obtaining information about the prevailing conditions and the efficacy of policies and programs in general and agricultural research and extension

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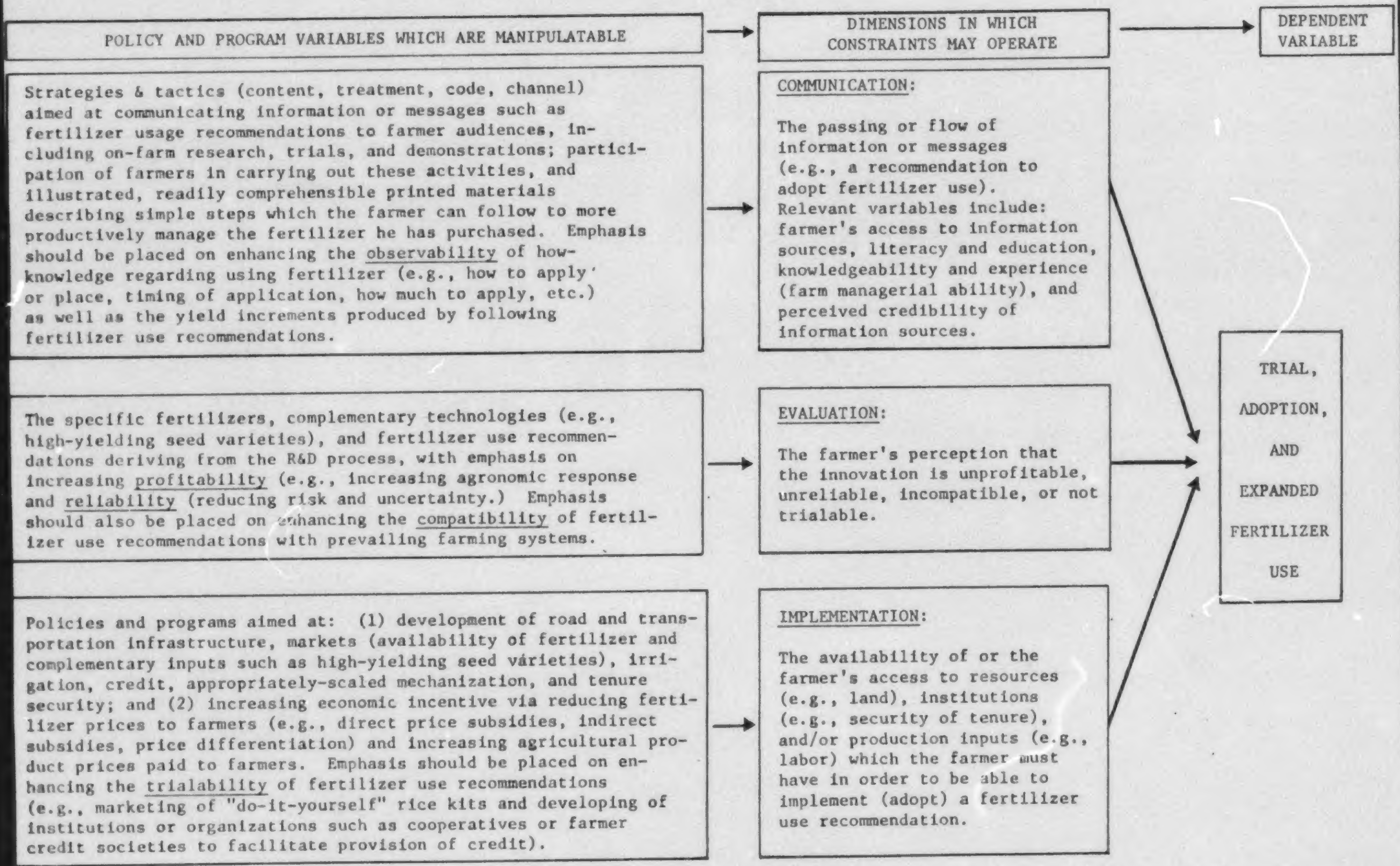
[64] There is a sizable body of literature in the area of land tenure and land reform which is relevant to an evaluation of the relationship between tenancy and fertilizer use. Alternative interpretations of this literature are available in Cheung (1969), Palmer (1976), Stevens (1977:239, 242-244), Roumasset (1979), Roumasset and James (1979), and Baron (1980).



POLICY AND PROGRAM VARIABLES WHICH ARE MANIPULATABLE

DIMENSIONS IN WHICH CONSTRAINTS MAY OPERATE

DEPENDENT VARIABLE

Strategies & tactics (content, treatment, code, channel) aimed at communicating information or messages such as fertilizer usage recommendations to farmer audiences, including on-farm research, trials, and demonstrations; participation of farmers in carrying out these activities, and illustrated, readily comprehensible printed materials describing simple steps which the farmer can follow to more productively manage the fertilizer he has purchased. Emphasis should be placed on enhancing the observability of how-knowledge regarding using fertilizer (e.g., how to apply or place, timing of application, how much to apply, etc.) as well as the yield increments produced by following fertilizer use recommendations.

COMMUNICATION:

The passing or flow of information or messages (e.g., a recommendation to adopt fertilizer use). Relevant variables include: farmer's access to information sources, literacy and education, knowledgeability and experience (farm managerial ability), and perceived credibility of information sources.

The specific fertilizers, complementary technologies (e.g., high-yielding seed varieties), and fertilizer use recommendations deriving from the R&D process, with emphasis on increasing profitability (e.g., increasing agronomic response and reliability (reducing risk and uncertainty.) Emphasis should also be placed on enhancing the compatibility of fertilizer use recommendations with prevailing farming systems.

EVALUATION:

The farmer's perception that the innovation is unprofitable, unreliable, incompatible, or not trialable.

TRIAL, ADOPTION, AND EXPANDED FERTILIZER USE

Policies and programs aimed at: (1) development of road and transportation infrastructure, markets (availability of fertilizer and complementary inputs such as high-yielding seed varieties), irrigation, credit, appropriately-scaled mechanization, and tenure security; and (2) increasing economic incentive via reducing fertilizer prices to farmers (e.g., direct price subsidies, indirect subsidies, price differentiation) and increasing agricultural product prices paid to farmers. Emphasis should be placed on enhancing the trialability of fertilizer use recommendations (e.g., marketing of "do-it-yourself" rice kits and developing of institutions or organizations such as cooperatives or farmer credit societies to facilitate provision of credit).

IMPLEMENTATION:

The availability of or the farmer's access to resources (e.g., land), institutions (e.g., security of tenure), and/or production inputs (e.g., labor) which the farmer must have in order to be able to implement (adopt) a fertilizer use recommendation.

Figure 9. Diagrammatic Representation of Relationships Between Dependent Variable (Trial and Adoption of Fertilizer Use), Dimensions in which Constraints May Operate, and Manipulatable Policy and Program Variables.

efforts in particular in dealing with these conditions. It is in this context that a plan or model for the design, implementation, and evaluation of an effective agricultural research and extension program would be of the greatest assistance.

There is, of course, a considerable body of literature relating to project design, implementation, and evaluation, although the plan or model which would appear to be most effective is that one which would ensure a two-way flow of information between a target population of small farmers and those in charge of developing the policies and programs intended to benefit them. This latter group would include those who are responsible for developing new agricultural production technology as well as those who are responsible for ensuring that additional target audiences (e.g., marketing agents, fertilizer companies, banks, extension workers, etc.) in the necessary support system for agriculture are able to provide the services the farmer needs to be able to increase food and agricultural production and resource productivity through an expanded use of fertilizer-related agricultural production technology. For the interested reader, discussions of differing perceptions of what such a plan or model of two-way information flow might look like or include as its components are presented in several sources: Byrnes and Byrnes (1971); Roling (1974a, 1975); Byrnes (1975); Pinstrup-Andersen and Diaz (1975); Morss, *et al*. (1975); Whyte (1975a, 1975b, 1977, 1978); Benor and Harrison (1977); the work of ICTA (1977) as documented in Fumagelli and Waugh (1977), Hildebrand (1976, 1977a, 1977b, 1978), and Waugh (1975); Harwood (1979); Koppel (1979); Nagel (1979); Pinstrup-Andersen (1979b); Winkelman and Moscardi (1979); and Norman (1980).

Also relevant are a number of studies and reports on experiences in fertilizer use promotion in developing countries (Alix, 1972; Lee, 1978; and Zshernitz, 1979). Information in this respect is sometimes available on a country-specific basis as in the case of India where publications such as *Fertiliser News* and *Fertiliser Marketing News* frequently carry articles on fertilizer use promotion (cmpr. Rahudkar, 1958; Kothari and Murty, 1969; Indo-German Fertilizer Educational Project, 1975; Subramoney, 1976; Choudhary and Prasad, 1977, 1978, 1979a, 1979b, 1980; Ambasta, 1978; Tandon, 1978; Das, 1979; Dhua, 1979; Dwarakinath, 1979; Gami, 1979; Gowda, 1979; Heredia, 1979; Jayaraman, 1979; Rao, 1979; Singh, 1979; Anand, 1980; Bhattacharyya, 1980; Sodhi, 1980; Sridhar, 1980; and Thomas, 1980).

CHAPTER VIII

METHODOLOGICAL IMPLICATIONS

AN ASSESSMENT OF THE RESEARCH APPROACHES REVIEWED

Since Chapters II-V provide detailed critiques of individual approaches to diffusion research in the developing countries, the discussion here is limited to drawing several general conclusions regarding the approaches reviewed. First, those approaches reviewed and summarized in table 32 provide a resource for researchers to draw upon in the future in developing and/or adapting an improved methodology for studying the diffusion of fertilizer use or any other innovation in agricultural production technology. However, none of the approaches reviewed stands out as "the" best approach to conducting diffusion research in the developing countries. While specific merits as well as deficiencies in each approach were noted in detail in the review, the main point to be emphasized here is that previous diffusion studies have largely been carried out along disciplinary lines and researchers from different disciplines have rarely attempted to work on a collaborative, multidisciplinary basis in conducting diffusion research. Additionally, diffusion researchers have tended to limit the scope of their studies to the variables and/or approaches which were emphasized in the particular discipline in which they were professionally trained and have rarely attempted to apply any one approach on a replicated basis in different geographical locations. Consequently, alternative and competing perceptions have tended to prevail regarding the relative importance of the variables determining how quickly an innovation will diffuse.

Within the broad range of research approaches reviewed, studies focusing specifically on the adoption and/or diffusion of fertilizer use in the developing countries are few and far between. Thus, only a few studies are available which specifically address in any detail the problem of identifying and estimating the relative importance of the factors which are influential in determining the rate of diffusion of fertilizer use (cmpr. Shetty, 1966; Kolshus, 1972; Falusi, 1973, 1974; Colmenares, 1975a, 1975b; Aklilu, 1976; Gladwin, 1976, 1977; Ahmed and Sadiq, 1976). A significant shortcoming in many of the diffusion studies reviewed is that the research has been based largely on a study of cases in which the interfarm diffusion process was already partially completed in that a relatively large number of farmers had already adopted the innovation in question.

Typically, in such studies, the emphasis is on providing *ex post* explanation of adoption behavior rather than providing a basis for estimating (1) the relative importance of the factors which act as constraints to adoption when the process of diffusion is beginning to unfold; and (2) the additional number of farmers who would be expected to adopt in each time period if the identified constraints are removed or relaxed through appropriate policies and/or programs. Thus, the information on an innovation's diffusion produced by explaining variations among farmers in their degree of innovativeness or among districts in the slopes of logistic curves provides an extremely limited basis for designing policies and programs to relax or remove existing constraints and, thereby, accelerate the innovation's rate of diffusion or increase the level or intensity of use of this innovation among farmers already using it. In developing an improved methodology for studying the diffusion of fertilizer use and other innovations in agricultural production technology in the developing countries, greater attention should be directed to the development and testing of models that (1) specify the factors which operate in each time period as constraints to adoption and (2) estimate the relative importance of these constraints. Without such knowledge or, more importantly, methodologies for producing such knowledge, policy making and program implementation to accelerate the diffusion of fertilizer use and other innovations in agricultural production technology will not be effective in achieving the results desired.

The empirical results reviewed herein are drawn from diffusion, adoption, and related studies conducted in over 25 developing countries in Africa, Asia, and Latin America. However, very few of these studies were conducted in a way that would test the extent to which a methodology can be applied in a variety of geographical locations. One exception to this generalization is evidenced in the case of innovativeness analysis which was used by Rogers, *et al*. (1970) in a series of diffusion studies in Brazil, India, and Nigeria. However, as earlier indicated, the research approach (i.e., innovativeness analysis) used in this tri-nation study was not without methodological shortcomings among which was the failure to include a broader range of potentially significant explanatory variables.

An important factor determining the generalizability--geographical or otherwise--of any research approach to the study of the diffusion of innovations in agricultural production technology in the developing countries is whether the research approach used incorporates a means for taking into account the realities and potential influence on adoption of topographical and agro-climatic variability in the area studied. A consideration of this factor, for example, would have provided a rationale for Roumasset (1973) to seek to study rainfed as well as irrigated rice-producing areas of the Philippines. Although Roumasset's study did not focus on the diffusion of fertilizer use, we may learn from his study that a methodology for studying the diffusion of innovations in agricultural production technology is strengthened by providing some means to take into account specific agro-climatic factors bearing on farmer decision making regarding whether to adopt recommended agricultural practices. There is no use in seeking economic or sociological explanations for non-adoption if the innovation itself is not agronomically appropriate to the agricultural areas for which it has been recommended (Ashby and Coward, 1980).

In carrying out a diffusion study, care must also be taken to ensure that the research approach used incorporates a procedure for assessing the extent to which adoption will be affected by the existing market for the crop that would be produced in conjunction with use of yield-increasing technology (e.g., fertilizer use). Such technologies are typically cost-increasing, relative to the farmer's current technology, and unless the farmer is confident that using the innovation will increase the return from his crop enough to cover the additional expenses it incurs, he is not likely to use it. Similarly, additional monetary income does not necessarily improve the farm family's real income or level of living unless adequate opportunities are available to channel the increased cash flow into providing for an improved diet (e.g., milk, meat, fruits, and vegetables), acquisition of consumer goods (e.g., shoes, bicycles, sewing machines), and/or investment in land, productive inputs, or interest-earning savings. Where the farmer is convinced that an increased cash flow will place such opportunities within his grasp, he is more likely to adopt the innovation.

Finally, the utility of existing approaches to the study of an innovation's diffusion has been limited in the extent to which such approaches have been applied only on a one-shot basis (e.g., a dissertation which for all practical purposes remains unknown) and without any followup. Ideally, followup would consist of using a study's findings, conclusions, and recommendations as a basis for formulating policy and program recommendations that would be expected, if implemented, to result in a faster rate of diffusion of yield-increasing innovations.

Without followup, the knowledge produced by such studies remains a matter of only academic interest. To avoid such a limited outcome, diffusion studies must be designed with an eye as to how their possible results or outcomes can be translated into recommendations of ways in which existing policies and/or programs can be changed to facilitate an accelerated rate of diffusion. This objective can best be met by designing diffusion studies with a greater emphasis on conducting these studies as an integral part of the research process involved in developing agricultural production technology for small farmers.

RESEARCH TOPICS AND QUESTIONS

There are a number of areas in which research is needed to improve our understanding of the ways in which potential constraining factors delay or block an accelerated diffusion of fertilizer use in the developing countries (cmpr. Ahmed and Sadiq, 1976:39-40).

The adoption of fertilizer use involves the farmer, to an even greater extent than he previously may have been, in commercialized agriculture and the market economy. This fact is evidenced by the new roles which the subsistence farmer must play with respect to suppliers of credit and inputs and to purchasers of output. What is the relative importance of factors, such as farm size, tenancy, and capital (credit) availability in ensuring that the farmer is able to play the role of a "commercial farmer"?

The adoption of fertilizer use is likely to have significant implications for the quantities of other variable inputs used by the farmer or vice versa. If fertilizer use is adopted, what will be the impact on the demand for fertilizer-responsive, high-yielding seed varieties, labor, water, other chemical inputs such as pesticides, insecticides, herbicides, and selective mechanization in the form of implements and machinery? To what extent will the lack of such inputs impede the adoption of fertilizer use? To what extent can the farmer compensate for a lack of one input (e.g., herbicides) by using a substitute (e.g., weeding by hand)? These considerations raise a further question: Does fertilizer use occupy a specific step in a general pattern or trend of practice or innovation adoption?

While the criterion of profitability is frequently emphasized in diffusion studies by economists, too many diffusion studies have failed to include a measure that would objectively assess whether the innovation being studied would indeed be profitable for the farmer who has not adopted it. Research is particularly needed to develop procedures for estimating whether fertilizer use would be as profitable on the farms of the nonusers as it is on the farms of those farmers who have adopted this practice. Such objective measures could then be compared with measures of the nonuser's view of the innovation's profitability.

Is there a minimum set or pattern of favorable perceptions of fertilizer use or a set of practices involved in using fertilizer which the farmer must develop in order to reduce or overcome the technical, economic, and social risks the farmer may perceive as being involved in adopting fertilizer use? The highly stochastic nature of a crop's response to fertilizer under rainfed conditions, in conjunction with the limited resources available to the smaller farmer, points out the importance of high reliability (low risk) as an essential characteristic of any technological package which includes using fertilizer. Improvements in the measurement of risk-related variables would also provide a basis for comparing the influence of such variables on the farmer's perception of an innovation's reliability. Research on developing improved measurements of risk-related variables and the perceived reliability of new technologies is particularly needed to identify technological alternatives which are profitable and still relatively low in risk (high in reliability). Particular attention should be directed to determining the impact on reliability or risk of various intervening variables (e.g., the farmer's net worth, irrigation and water control, commodity price fluctuation, etc.).

Additional contributions could be made by the development of improved measures of such other perceived innovation attributes as compatibility, observability, and trialability. An ability to measure such perceptions before extensive campaigns are launched to promote adoption of an innovation could provide valuable information regarding any deficiencies in an innovation that would delay or block adoption of that innovation. Such information could then be used to identify needed modifications in the innovation, in the manner in which the innovation is to be used by farmers, or in the agri-support system which provides services essential for the profitable utilization of the innovation.

Scattered evidence indicates that small farmers may have difficulty in understanding recommendations for fertilizer use at the farm level in the form in which they are given, thus making it more difficult for the farmer to evaluate them. The evidence suggests a number of important questions: Do recommendations take into account the type of fertilizer which the farmer should use and the appropriate rates of application for his farm's soil and crop nutrient requirements? In areas where there are considerable differences in soil composition, nutrient requirements, and/or cropping systems, or where farmers have limited ability to decide which fertilizer is best or the appropriate rate to use in applying it, do the recommendations help the farmer adjust the recommendations to his particular farming situation? In general, do we really know how to make fertilizer recommendations to farmers? How can we improve the manner in which fertilizer recommendations are communicated to farmers, so as to ensure that they adequately understand and appropriately respond to the agronomic and economic considerations involved.

The farmer's managerial ability and knowledge about fertilizer use will become increasingly important in ensuring the economically sound use of fertilizer. Improved information about the farmer's managerial ability and level of knowledge about and understanding of fertilizer use would greatly facilitate the preparation of fertilizer use recommendations that would be readily understood by the farmer. Thus, research is required to identify what level of knowledge about fertilizer use is minimally required on the part of the farmer to ensure that he will properly use this input. This will require development of procedures for measuring existing levels of farmer knowledge about fertilizer use, as well as procedures whereby the farmer's level of knowledge, when deficient, can be brought up to the level required to ensure that he wisely uses fertilizer. Can these deficiencies on the part of the farmer be corrected through alternative educational or extension approaches and/or fertilizer delivery (marketing) systems?

The credibility of information sources can significantly influence whether or not farmers decide to adopt an innovation. Research is needed to identify the dimensions of credibility which inspire the farmer's confidence in the change agents. From the farmer's viewpoint, what is the relative importance of technical, economic, farming, communication, and science competencies of the change agent?

Where adoption of fertilizer use is promoted by an extension worker, what evidence does the farmer minimally require of a demonstration of fertilizer use to ensure rapid adoption and diffusion of this innovation? How can fertilizer demonstration and marketing programs be designed to provide the farmer with greater opportunity to 'witness' the evidence which he requires for adoption?

Can fertilizer use be initially introduced to, tried out, and adopted by smaller farmers, with a subsequent diffusion of this technology to other farmers in the surrounding region? If this is possible, what are the minimum conditions necessary in order for fertilizer use to diffuse to other small farmers? For example, diffusion of an innovation requires that information about the technology be passed from one farmer to another. One area which particularly merits further investigation in this regard is the development of a better understanding of the way in which personal communications between two or more people facilitate or impede the flow of such information. This is an important topic to which communication scientists and sociologists should direct increased research effort, particularly in exploring the possibility of applying network analysis to the study of the diffusion of fertilizer use (Rogers, 1976; Richards, 1975).

Social factors such as caste and class differences obviously affect the pattern of communication of information about and the diffusion of fertilizer use. However, research designs which include such variables should also include and attempt to assess the relative impact on adoption of social or system level variables which can be manipulated or influenced by action programs (e.g., the level of village leadership or farmer participation in organized groups).

Can measurement procedures be developed to estimate the increases in adoption that would be expected to occur if one or a combination of constraints to adoption of fertilizer use were relaxed or removed? What are the relative impacts on adoption levels of changes in pricing policies, institutional constraints, marketing programs, and education and extension (demonstration) programs?

Knowledge of the fertilizer demand parameters in developing countries is limited. Additional research is needed to specify these parameters and their relative importance in short- and long-run demand functions. Improved information on the number and distribution of small farmers who have adopted fertilizer use as well as their level of fertilizer use, is a potential source of data for developing more precise aggregate estimates of a country's demand. How can data on demand for fertilizer at the small farm level be used to improve the estimates of demand for fertilizer which are needed for decision making on investment in and public policy regarding fertilizer use? Additional research is needed to specify input elasticities of substitution and labor market interactions. Research in these areas should add understanding of the factors underlying fertilizer demand, improve the predictive ability of fertilizer demand functions, and improve fertilizer demand forecasting.

APPENDIX

RISK ANALYSIS

Dillon (1976) and Anderson (1976) provide excellent points of departure for a more detailed review of the literature on risk. While limitations of space do not permit review of even all of the more recent methodological approaches in risk analysis, two research approaches are briefly highlighted: (1) lexicographic safety first models and (2) stochastic dominance models.

Lexicographic Safety First Models

Use of lexicographic safety first models is illustrated in Roumasset's study (variously reported in 1973, 1974a, 1974b, 1974c, 1975) of the impact of risk preference on the level of nitrogenous fertilizer applied by Philippine rice farmers. One of the principal contributions of the methodology used by Roumasset is that it provides a means to compare (correlate) the actual level of nitrogen used by farmers with the optimal level of nitrogen under different behavioral assumptions about the farmers' neutrality or aversion to risk:

1. The farmer maximizes expected profit (e.g., Dillon, 1976).
2. The farmer maximizes expected profits if the Safety First constraint is met.[65] If this constraint is not met, then the farmer minimizes the probability of disaster. Roumasset calls this strategy or behavioral assumption the "Lexicographic Safety First (LSF_1) model.
3. The farmer maximizes expected profits if the Safety First constraint is met. If this constraint is not met, then he follows the Safety-Fixed Principle, i.e., he maximizes the minimum return that can be obtained with a probability of at least the crucial P*. This is Roumasset's LSF_2.

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[65] Specifically, the Safety First constraint is defined as the Pr (profits < d) < P*, i.e., the probability of profits less than d, a level of disaster or ruin, must be less than an exogenously specified crucial probability P*.

4. The farmer maximizes expected profits subject to the constraint that the probability of a negative internal rate of return to fertilizer is less than a specified confidence level (Pi) for farmer i. Here, Roumasset is assessing de Janvry's model (1972).

Correlating actual levels of nitrogen applied per hectare by Philippine farmers with the optimal levels under the different behavioral assumptions, Roumasset found that the actual level of nitrogen correlated most highly (r = .87) with the optimal level for the first behavioral assumption (maximize expected profits), i.e., the risk-neutral model.

Roumasset's study is to be credited for its (1) integration of agro-biological experimental data (i.e., a production function estimated from crop-fertilizer response experiments and cross-sectional data) and (2) development, via the "Risk Sensitivity Index" (Roumasset, 1973:143), of a methodology for relating actual output (yields) and inputs (e.g., quantity of fertilizer used) to a measure of the minimal output which a farmer must produce in order to avoid disaster (e.g., not fall below a subsistence level of income). It must be emphasized, however, that the validity of Roumasset's approach to the study of risk was considerably weakened by the fact that his sample was drawn from a population of farmers who cultivated irrigated fields rather than rainfed rice holdings. Thus, while an increased level of fertilization did promise higher profits, there was little or no corresponding increase in the level of risk as would more likely have been the case if the study had been conducted on rainfed holdings.

Two additional weaknesses in Roumasset's study also merit comment here. First, Roumasset's research provided estimates of the differing quantities of nitrogenous fertilizer that farmers would be expected to apply if their behavior were consistent with one or another of the four distinct behavioral conditions. Although three of these conditions assume that the farmer is averse to risks in one form or another, the empirical situation studied (i.g., irrigated rice holdings), as noted above, could hardly be described as a "risky environment." It would seem obvious that an hypothesis of the type "risk-averse farmers do not apply significantly less nitrogenous fertilizer than non-risk-averse farmers" could only be adequately tested on data pertaining to farmers who are indeed operating in a "risky environment" with respect to the profitability and reliability of agronomic and economic returns to the application of fertilizer.

Second, the methodology used in Roumasset's study neither provides direct measures of the farmer's perceptions, attitudes, or preferences in relation to risk nor demonstrates that farmers significantly differing on any such measures apply any significantly different quantity of fertilizer than farmers who are the same on the measures of risk. Instead of assuming how farmers might behave (e.g., how much nitrogenous fertilizer they would apply) if they were averse to risks, future studies should place greater emphasis on developing direct measures of the farmer's perceptions, attitudes, or preferences with regard to risk and utilize this information as a basis for determining whether aversion to risk has a significant effect on the decision-making of farmers (e.g., whether to adopt a new fertilizer or to significantly increase the rate of application).

Stochastic Dominance Models

Another approach to assessment of differences between technologies in the level of risk is based on the use of stochastic dominance (SD) models (Anderson, 1974; Hardaker and Tanago, 1973; O'Mara, 1971, 1972, n.d.; Scobie, *et al*., 1976). SD models consist of "rules for identifying unanimous preferences by...utility maximizers among completely specified risky prospects" (Anderson, 1976:14). Although it is not necessary to enter into detail about the substance of the various rules, the basic idea is that farmers (who are assumed *both* to avoid risks *and* to maximize expected utility) will prefer an alternative that gives a dominant probability distribution, i.e., a technology having a probability distribution whose lower bound and mean cannot be less than the lower bound and mean of any other alternative distribution that is available.

One application of an SD model is provided by Scobie, *et al*. (1976) who compared two agricultural production technologies: (1) a modern technology consisting of improved seed and requiring high labor input and land preparation costs, and (2) a traditional technology consisting of a seed variety requiring low labor input and other costs. A production function was estimated for a cropping system of corn and sesame from data on 100 farms in Costa Sur, Guatemala. Additionally, a probability distribution of returns from each system (traditional and modern) was estimated by means of a Monte Carlo simulation of a distribution of 100 randomly selected coefficients B_i for each input variable in the estimated production function: input expenses, area planted, and number of person-days of labor. The resultant sets of B_i were then introduced into each of the two estimated production functions, along with information on input and product prices. This produced two different distributions of net returns, one for the traditional technology and the other for the modern technology. This information thus provided an estimate of what the distribution of net returns might be over 100 cropping seasons for each technology. Table 34 provides the expected mean and variance for each technology and illustrates that a decision about which technology to recommend to the farmer would be difficult without making some further assumption about the individual's utility function.

The approach used in a SD model, however, provides one means of overcoming this impasse. Arranging the simulated levels of return for each technology in increasing order from low to high, approximating the cumulative probability distribution for each technology, and applying the various data manipulative techniques and statistical criteria utilized in SD modeling (e.g., see Anderson, 1974, 1975; or Hardaker and Tanago, 1973), Scobie, et al., (1976) found that the traditional technology dominated the modern technology. Thus, the researcher is provided with an independent basis for predicting that farmers are likely to consider the modern technology as too risky and, consequently, probably will not adopt the modern technology if it is recommended to them.

Scobie, et al. (1976:14) suggest that the methodology of SD models could be readily applied to data on the response of several varieties under different ecological conditions. This would provide a basis for determining which variety to recommend as the least-risk alternative to the farmer's existing variety. Another application of SD modeling is reflected in O'Mara's (1971, 1972, n.d.) research on measurement of dominance as perceived by the farmer. Thus, the technique of SD models is seen to be one methodology which could be used to assess how closely the farmer's concept of risk corresponds to the risk as measured by agroeconomic data. Accordingly, the approach of SD models may yet withstand Gladwin's observation that the technique, as it is applied in such research and reported in Anderson and Scobie, et al. (1976),

> ...uses agronomists' estimates of yields and probabilities, so that agronomists, not decision makers, define what the alternatives are. Then naturally [the] conclusion...[is] that "'risk-averse' farmers should adopt...[the alternative that is dominant]...irrespective of their own particular attitudes to risk"

Table 34. Expected Means and Variances of the Distribution of Returns from Traditional and Modern Technologies in Costa Sur, Guatemala (Scobie, *et al*., 1976)

Technology	Expected Mean	Variance
Traditional	884.3	3.2×10^6
Modern	2,995.4	30.9×10^6

(Anderson, 1974:156). We should all know by now that what farmers should do and what they do do are two different things (Gladwin, 1975b).[66]

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[66] The first two sets of brackets inserted by the present author.

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[1] A citation bearing an "n.d." denotes that the document in question did not indicate a date of publication. A citation bearing an asterisk (*) prior to the year (e.g., "*1976") denotes that the study in question focuses specifically on adoption/diffusion of fertilizer use, estimation of demand for fertilizer, or supplementary material relating to fertilizer.

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